Empirical Investigation on Exchange Rate Volatility and Trade Flows in Nigeria

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Abstract

This paper investigated the impact of exchange rate volatility on trade flows in Nigeria using monthly data for the period 1997 – 2016. A GARCH model was used to generate the nominal exchange rate volatility series. To detect the long-run relationship among variables, the ARDL bounds testing approach was employed. Also, the Granger causality test was applied to ascertain the direction of causality among the variables. The study found that exchange rate volatility affected Nigeria's trade flows negatively, in the short-run but does not in the long-run. As such the Central Bank of Nigeria would find some trade benefits from intervening immediately to stabilise the foreign exchange market in the face of volatility. Also, the study showed that ignoring exchange rate volatility could negatively impact on Nigeria's trade flows especially in the short-run.

Keywords: Volatility, Exchange Rate, Trade Flows

JEL Classification: *F31, F10, C5*

I. Introduction

Since the fall of the Bretton Woods agreements in 1973, the effect of exchange rate instability or volatility on trade flows has been a major debate among academics and policymakers alike. According to Asteriou et al. (2016), in countries where exchange rate volatility had adverse effects on trade flows, more stable exchange rate through central bank intervention in the foreign exchange market will help to boost their trade. Investigating the significance of this relationship for Nigeria is very timely and relevant for improved economic performance given that crude oil export, which is very volatile, is the primary source of Nigeria's foreign exchange. In Nigeria, since the adoption of the Structural Adjustment Programme (SAP) in 1986, several institutional framework and management strategies have been practiced in a bid to achieve exchange rate stability and policy; from the Second tier Foreign Exchange Market (SFEM) to the fully liberalised Foreign Exchange Market (FEM). Following continued volatility and instability over exchange rates, more policies were introduced. These include the Autonomous Foreign Exchange Market (AFEM), Inter-bank Foreign Exchange Market (IFEM), Dutch Auction System (DAS), the Wholesale Dutch Auction System (WDAS) and the Retail Dutch Auction System (RDAS).

Given that the determinants of exchange rate volatility change from time to time depending on the structural dynamics associated with the market, the frequency of volatility is difficult to measure (David et.al, 2016). There is a growing agreement in the literature that a prolonged and substantial exchange rate misalignment can create macroeconomic imbalances, and the correction of external balance will require both exchange rate devaluation and demand management policies. Numerous studies were conducted on Nigeria and particularly on the extent of naira exchange rate and its misalignment. These include Ali et al. (2015) which investigated the impact of Naira Real Exchange Rate Misalignment on Nigeria's economic growth using quarterly data spanning 2000 to 2014. Similarly, Ibrahim (2005) examined the impact of real effective exchange rate misalignment on economic growth in Nigeria using annual data spanning

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1960 to 2011. The paper used the augmented growth model estimates using purchasing power parity (PPP) and generalised method of moment (GMM) approaches. However in these studies, the impact of exchange rate volatility on trade flows was missing, and thus us considered critical.

The main contribution of this paper therefore, is to use the GARCH modeling technique combined with the ARDL bounds testing approach to examine the impact of both nominal and real exchange rate volatilities on monthly export and import volumes of Nigeria for the period, 1997 – 2016. The study would provide empirical evidence to drive policy formulation in the management of exchange rate as it impacts on trade and provides information that could guide more studies on the subject. The rest of the paper is organised as follows. Section II presents stylised facts on exchange rate and trade flows, while section III provides the review of related literature. Section IV discusses the data and methodology employed in the study. Finally, Section V contains conclusions and policy recommendations.

II. Exchange Rate and Trade Flows in Nigeria

This section dwells on the stylised facts on exchange rate developments and trade flows in Nigeria. In addition, the factors that influence trade flows are also discussed below.

II.1 Factors that Influence Trade Flows in Nigeria

II.1.1 Global Economic Developments

Developments in the global economy impact directly on Nigeria's trade flows due largely to the fact that the Nigerian economy is integrated into the global economy following the reduction of trade barriers by most nations. Trade, being an important engine of integration transmits economic disturbances between nations[1]. The lingering effect of the Global Financial Crisis and the slow recovery of most industrialised and emerging economies has weakened global trade and affected global demand particularly for commodity exports. In addition, the overbearing influence of the oil sector on the Nigerian economy underscores the importance of external developments to trade flows. Crude oil export has remained dominant and the highest foreign exchange earner for the country since the 1970s. Therefore, developments in the international crude oil market, particularly oil price, significantly affect the performance of Nigeria's trade.

Over the years, crude oil price, like other commodity prices experience swings in times of shortage or oversupply. In recent times, the global oil market has witnessed high levels of price volatility. Since the last quarter of 2014, crude oil prices witnessed a slump as a result of supply glut. The entrance of the US shale oil into the international oil market, weak global demand, huge oil inventory in Europe and the appreciation of the US dollar were some of the factors that also contributed to the slump in crude oil prices. The average price of Nigeria's reference crude, Bonny Light, decreased from US$102.63 per barrel in August 2014 to US$63.19 per barrel in December 2014. It maintained a downward trend all through 2015 and 2016 reaching an all-time low of US$31.21 per barrel in January 2016.

[1] Mussa, 2000: Factors Driving Global Economic Integration

Consequently, oil export which was ₦12, 989.82 billion in 2014 declined to ₦9,016.32 billion and ₦8,769.32 billion in 2015 and 2016, respectively.

II.1.2 Trade Policies

The overall objectives of Nigeria's trade policy is the encouragement of production and distribution of goods and services to satisfy both domestic and international markets for the purpose of achieving accelerated economic growth and development (Jamali and Anka 2011).

Nigeria's trade policies are largely governed by the regional considerations and her membership of international organisations such as the World Trade Organisation (WTO), Economic Community of West African States (ECOWAS) and African Union (AU). Nigeria's foreign trade policy is centered on two broad strategies namely, import substitution strategy (ISI) and export-led growth strategy. The ISI strategy was adopted in the 1960s and involved the use of tariff and non-tariff barriers to protect domestic manufacturing industries. Tariff barriers include the use of high import duties, while non-tariff barriers are quantitative restrictions such as quotas and subsidies. The recent restrictions on access to foreign exchange from the official window for 41 categories of import and other demand management policies are some of the recent ISI strategies embarked upon by the government with the aim of conserving foreign exchange and resuscitating domestic industries.

The export-led growth strategy involves the use of industrialisation strategy to promote the export of domestically produced goods of which the country has a comparative advantage. The objective was to boost foreign exchange earnings and diversify the foreign exchange base of the economy. Several measures were implemented to ensure the success of the strategy in the promotion of non-oil export. These include the establishment of export processing zones; implementation of lower tariff structure designed to stimulate competition and efficiency; custom and port reforms; and adoption of the ECOWAS five-band common external tariff. These policy measures basically determine the level of trade in a country. Favourable trade policies also determine the importance of trade and also give a direction to the extent of a country's level of integration of the economy to the world.

II.1.3 Competitiveness

Competitiveness plays an important role in the performance of trade as it is regarded as the measure of a country's ability to efficiently provide different products and services to other countries[2]. Competitiveness provides opportunity for countries to maximise their potential, opens up economic opportunities, and improves efficiency. Competitiveness affects a country's trade in terms of prices (exchange rate and inflation) and productivity. The composition of Nigeria's export and the level of diversification also affect competiveness. Nigeria is a mono-cultural economy dominated by crude oil export with dismal progress in diversifying the export base, despite government's effort.

Nigeria's external competitiveness is measured in terms of trade openness, and the movement in real effective exchange rate (REER). In terms of trade openness as measured

[2] Dubravska and Sira (2015): The Analysis of the Factors Influencing the International Trade of the Slovak Republic

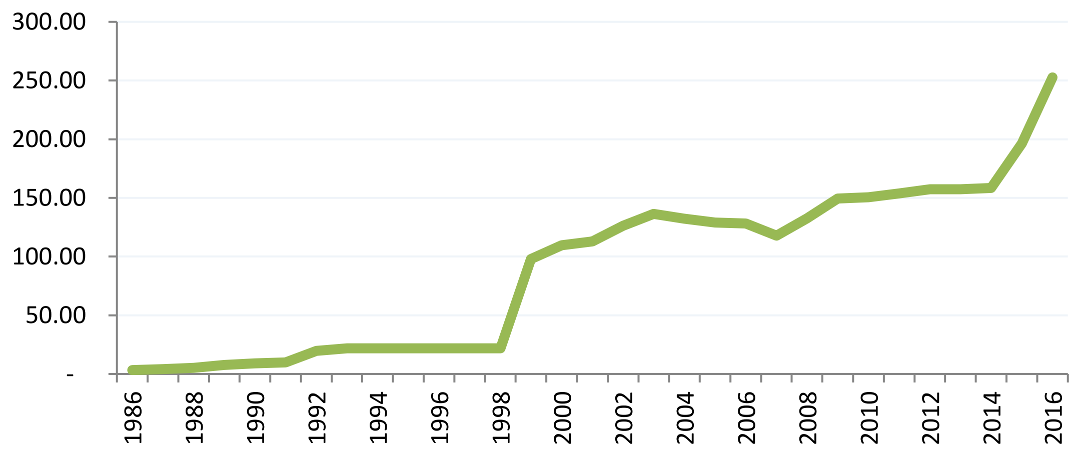
by the ratio of total trade to Nigeria's gross domestic product (GDP), Nigeria is considered to be moderately integrated with a ratio of 45.7, 55.0, 69.0, and 33.6 per cent in 2000, 2006, 2008 and 2012, respectively. It, however, dropped gradually to 23.9 per cent in 2016 due to significant drop in trade. A measure of Nigeria's external competitiveness in terms of REER index calculated using 13 countries as major trading partners showed an annual average REER index at 97.4 in 2009, which improved to 89.8 and 69.5 in 2011 and 2014, respectively. However, with the adverse impact of commodity price shock which led to significant depreciation of the naira exchange rate and higher domestic inflation, the REER index deteriorated to 70.8 and 78.7 in 2015 and 2016, respectively.

II.2 Exchange Rate Movements and Trade Flows In Nigeria

II.2.1 Exchange Rate Movements

The naira was introduced in 1973 to replace the Nigerian pound and the exchange rate was fixed at ₦0.65 to US$1. The Naira exchange rate was fixed for most part of the 1970s up to 1985. However, with the introduction of the structural adjustment program (SAP) in 1986, the foreign exchange market was liberalised and the naira exchanged for an average of ₦2.02 per US$1. It averaged ₦11.08 to a US dollar between 1987 and 1993 but depreciated to ₦22.00 in 1994 and was later fixed at ₦21.89 to a US$ by the federal government from 1994 to 1998 indicating a shift to fixed exchange rate regime during the period. The naira depreciated to ₦97.95 to US$1 following the liberalisation of the market in 1999. It averaged ₦125.00 to a US dollar between 2000 and 2006 and appreciated to ₦117.97 per US$1 in 2007. The stability in the exchange rate was as a result of the favourable terms of trade which led to the accumulation of external reserves. The adverse effect of the global financial crisis coupled with the decline in oil price led to excessive demand pressure at the foreign exchange market, which led to the depreciation of the naira to ₦149.58 to a US dollar in 2009 and further to ₦157.50 in 2012. The naira remained stable up to the third quarter of 2014.

Figure 1: Average Naira/US Dollar Exchange Rate



Source: CBN Annual Report (Various Issues)

The naira depreciated in the last quarter of 2014, due to heightened demand pressure. This led to the introduction of new reform policies at the foreign exchange market in November 2014. The reforms included the realignment of the exchange rate band by 200 basis points from ±3 per cent to ± 5 per cent and widening of the midpoint exchange rate from ₦155/US$1 to ₦168/US$1, as well as the exclusion of some invisible transactions from the official rDAS window. Consequently, the naira averaged ₦158.55 to a US dollar in 2014. The unabated demand pressure at the foreign exchange market, coupled with the continued decline in the nation's external reserves led to the closure of the official rDAS window in February, 2015 to curtail demand pressure and narrow the premium. In addition, the interbank rate was adopted for all eligible foreign exchange transactions. These measures and others abated the demand pressure and stabilised the exchange rate at an average of ₦196.49/US$ in 2015.

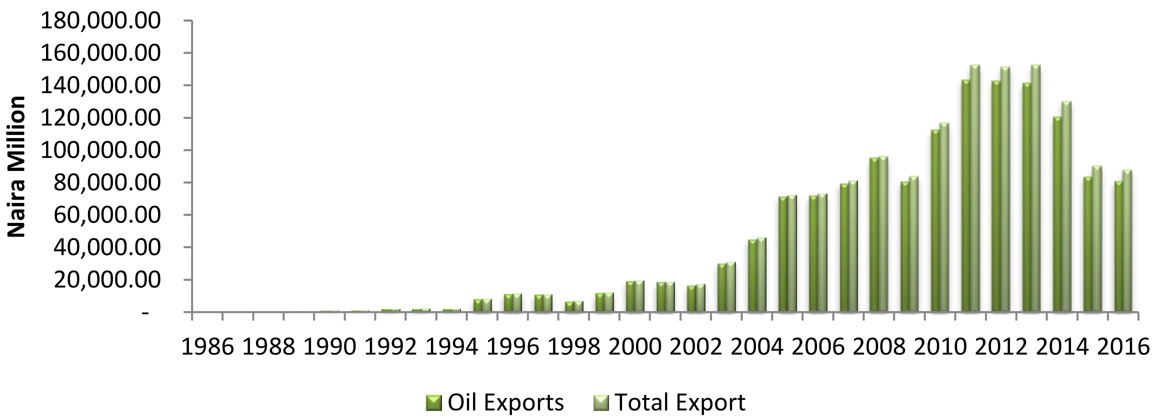
The Bank adopted a more flexible exchange rate regime in June 2016 which allows for greater flexibility in the determination of exchange rate. A 2-way quote system, futures market and foreign exchange primary dealers were also introduced. However, with the further decline in crude oil prices, resulting in increased demand pressure, the naira further depreciated to an average ₦253.19/US$ in 2016. In response, the investors' and exporters' window was introduced in April, 2017, which helped to stabilise the situation (Figure 1).

II.2.2 Trade Flows

II.2.2.1 Export

The export sector had been characterised by the dominance of one export commodity. Primary agricultural commodities were exported in the 1960s up to mid-1970s when Nigeria experienced a positive crude oil price shock. Since then, Nigeria has remained a major crude oil exporter. Over the years, the proportion of crude oil export in total export had increased remarkably, making it the dominant export commodity. Its share in total export has remained above 80.0 per cent up to 2005. For instance, the share of crude oil export in total export was an average of 97.5 per cent during the period 1999-2004. However, from 2005 when the country commenced the export of gas, the share of crude oil export reduced to an average of 88.0 per cent between 2005 and 2010 and further to 81.1 per cent of total export during the 2011-2015 period. Crude oil export accounted for 78.8 per cent of export in 2016. In terms of non-oil export, traditional agricultural commodity export remained dominant over the years followed by manufactured and semi-manufactured goods.

Figure 2: Oil and Total Exports

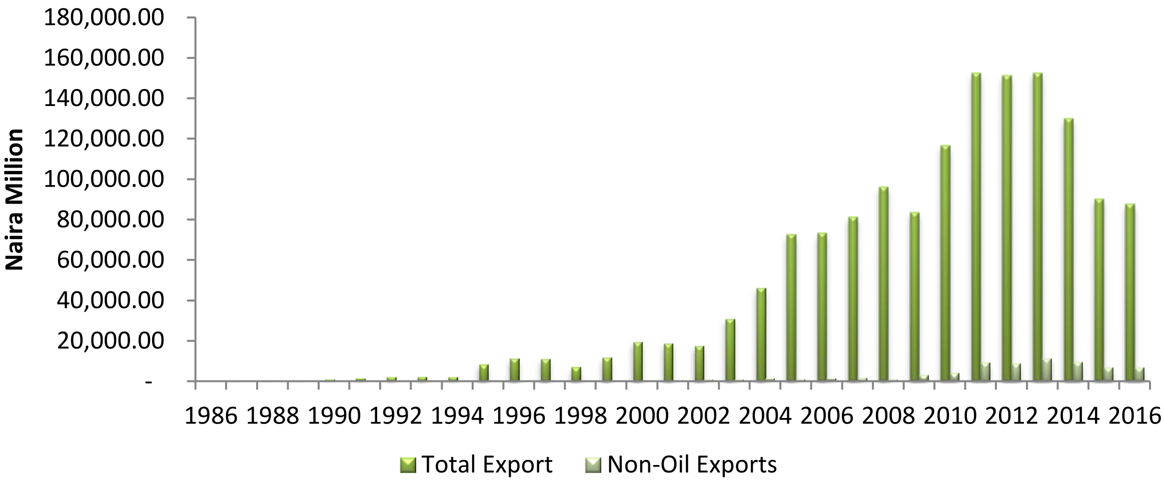


Source: CBN Annual Report (Various Issues)

In value terms, crude oil and gas export which averaged ₦45.33 billion between 1986 and 1990 rose to ₦307.66 billion during 1991 to 1995 as a result of favourable crude oil prices at the international market. It further increased to ₦1, 183.87 billion, ₦3,622.51 billion and ₦8,794.38 billion between 1996 and 2000, 2001-2005, and 2006-2010, respectively, reflecting favourable developments in the international oil market. Crude oil and gas export maintained an upward trend reaching a peak of ₦13,688.11 billion during 2011 to 2014 but however declined to ₦8,339.55 billion and further to ₦8,093.41 billion in 2015 and 2016, respectively due largely to the slump in crude oil prices at the international market and decline in domestic production during the period. In spite of the adverse development, crude oil and gas remained dominant accounting for more than 90.0 per cent of total export (Figure 2).

The contribution of non-oil export to total export remained dismal throughout the review period in spite of the government's effort to diversify the export base of the country. The value of non-oil export (mainly agricultural products) averaged ₦0.02 billion between 1986 and 1990 but rose to ₦0.07 billion and ₦0.08 billion during 1991-1995 and 2001-2005, respectively. It further rose to ₦0.22 billion and peaked at ₦0.97 billion from 2006-2010 and 2011-2014, respectively as a result of intensified government's effort to enhance value addition for export. However, the value of non-oil export declined to ₦0.68 billion in 2016 due largely to increased local demand, restrictions placed on some Nigerian agricultural goods from entering European markets due to non-compliance with international standards and high cost of production (Figure 3).

Figure 3: Non-Oil and Total Export



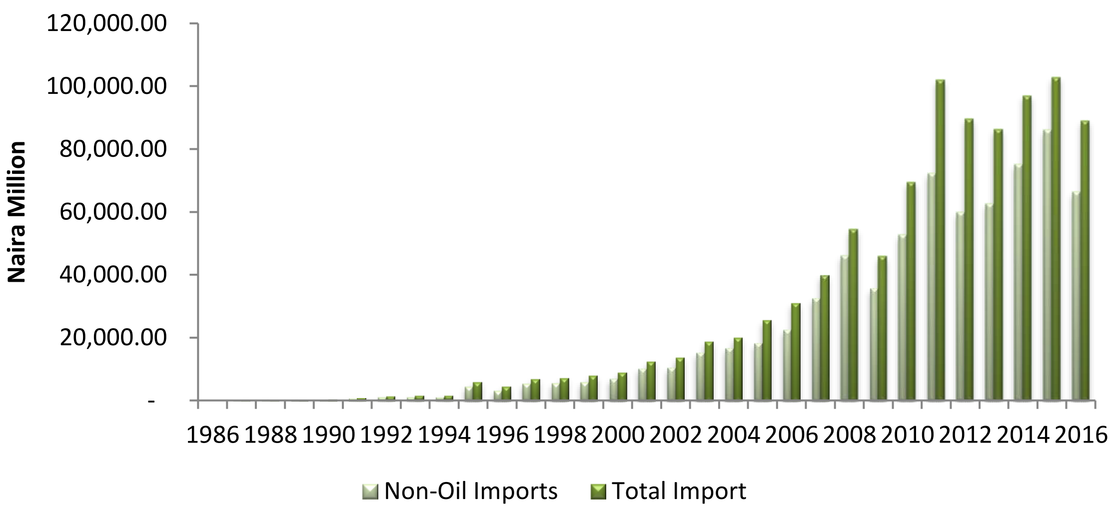
Source: CBN Annual Report (Various Issues)

II.2.2.2 Import

The structure of Nigeria's import has remained the same over the years with non-oil imports dominating total import. Within the non-oil import category, the share of capital goods and raw materials remained dominant due to government's effort to shore up the level of capacity utilisation and the ongoing rehabilitation of infrastructure in the country. The drop in Nigeria's refining capacity increased the share of oil import in recent years. For instance, the share of non-oil import averaged 23.8 per cent between 2012 and 2015 as against an average of 19.4 per cent between 2007 and 2011. It however stood at 25.4 per cent of total import in 2016.

As mentioned earlier, Nigeria's import is dominated by non-oil component consisting largely capital goods and raw materials. The value of non-oil import averaged ₦0.02 billion between 1986 and 1990. It grew gradually to ₦0.53 billion, ₦1,411.71 billion ₦3,792.14 billion during 1996-2000, 2001-2005 and 2006-2010, respectively as a result of increased demand to complement the Industrialisation drive of the government. Non-oil import maintained its upward trend averaging ₦6,751.28 billion and peaked at N8,613.94 billion from 2011-2014 and 2015, respectively. It however dropped to ₦6,643.09 billion in 2016 as a result of the demand management policies adopted by the CBN, high inflationary pressure and the depreciation of naira which made import more expensive (Figure 4).

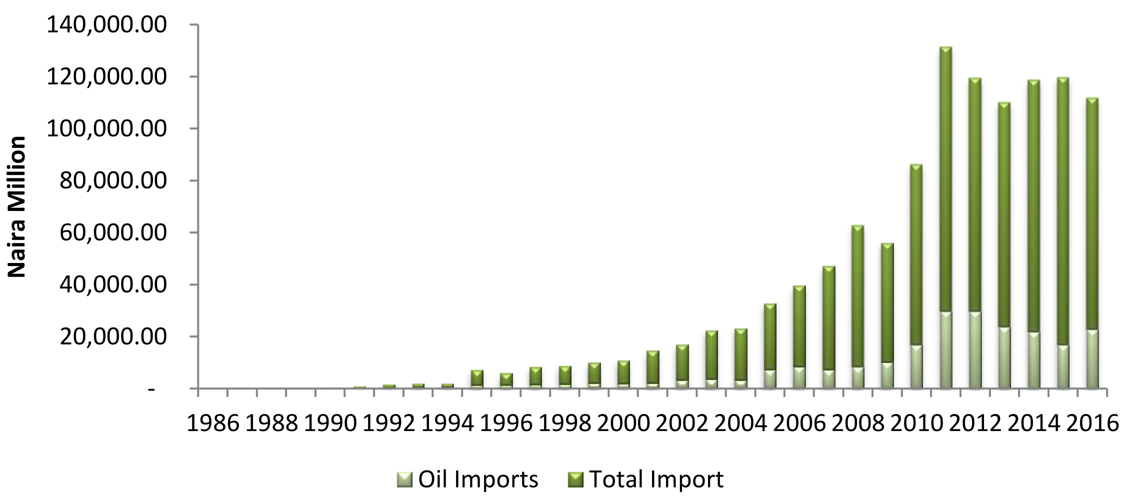
Figure 4: Non-Oil and Total Import



Source: CBN Annual Report (Various Issues)

In terms of oil import, the trend was also similar with lower value of less than ₦1.00 billion all through 1986 to 2008. However, due to the low domestic refining capacity, oil import gradually rose to an average of ₦1,878.74 billion and ₦2,295.81 billion during 2009-2011 and 2012-2015, respectively. It stood at ₦2,265.68 billion in 2016 (Figure 5).

Figure 5: Oil and Total Import



Source: CBN Annual Report (Various Issues)

III. Literature Review

III.1 Theoretical Literature Review

Most of the early works on the impact of exchange rate volatility on trade flows are based on partial equilibrium analysis and the behaviour of firms in the face of risk or uncertainty. The traditional school of thought holds that volatility increases risk of trade thereby depressing trade flows. The basis for their argument is on the fact that there exists a negative relationship between Exchange rate and trade flows. Clark (1973), Hooper and Kohlhagen (1978) explained this using a simple illustration of a firm under the following assumptions:

- Existence of a competitive firm with no market power producing only one good,
- Exports to one foreign market,
- There are no imported factors of production,
- Payments are made in foreign currency at the going rate; and
- No hedging possibilities

The illustration held that the supposed firm is solely an export-oriented firm which receives its payment in foreign currency and changes the proceeds of its transaction at the going (current) exchange rate, which is considered to be in fluctuation without predictability due to the assumption of the absence of hedging as maintained in this theoretical model. Under this circumstance of increased risk, as a result of volatile exchange rates and given that firms are profit oriented economic agents, a firm will be forced to rollback its exports rather than incur more adjustment costs to its established scale of production, in order to align with the direction of exchange rate volatility. Based on this thought process, proponents of this theory are of the view that there exists a negative relationship between exchange rate volatility and trade flows. Hence they considered not only the risk involved in doing business but also its degree.

III.2 Empirical Literature Review

There has been a wide but divergent range of studies and economic research works that seek to empirically analyse the nexus between exchange rate volatility and trade flows. In his work, Aliyu (2010) used the vector error correction and the VAR model to analyse the impact of exchange rate volatility on Nigeria's non-oil exports from 1986Q1 to 2006Q4. The result established a long-run stable and negative relationship between Naira exchange rate volatility and non-oil exports in Nigeria. In the alternative, the result was positive for the US Dollar exchange rate volatility and non-oil exports.

Joseph (2011) used the GARCH model on annual time series data of trade flows in Nigeria from the year 1970 to 2009. This study indicated that a negative and statistically insignificant transmission existed between exchange rate volatility and aggregate trade. The negative result though from annual time series data is in sync with that of Aliyu (2010). Dickson and Ukavwe (2013) also applied the error correction and GARCH model to investigate the impact of exchange rate fluctuations on trade variations in Nigeria using annual time series data from 1970 to 2010. The results of the study showed that exchange rate volatility is not significant in explaining variations in import, but was found to be statistically significant and positive in accounting for variations in export. Serenis and Tsounis (2014) examined the effect of volatility on two small countries, Croatia and Cyprus, on aggregate exports during the period 1990 to 2012. ARDL methodology was adopted and results suggested that there is a positive effect of volatility on exports of Croatia and Cyprus.

Ozturk and Kalyoncu (2009) used quarterly data of six (6) countries from the period 1980 - 2005 to investigate the impact of exchange rate volatility on trade flows in each of the countries, applying an Engle- Granger residual-based co-integration technique. The result showed a significant negative effect on trade in South Korea, Pakistan, Poland and South Africa and a positive impact on Turkey and Hungary. Mukherjee & Pozo (2011) studied the impact of exchange rate volatility on the volume of bilateral trade using a Gravity model from a sample of 200 countries and the result indicated a negative relationship although at a very high level of volatility, the effect diminishes and eventually becomes statistically indistinguishable from zero. Dell'Aricccia (1999) as well carried out an investigation on the European Union on the relationship between exchange rate fluctuations and trade flows using the gravity model and panel data from Western Europe. Evidence showed a negative effect of exchange rate volatility on international trade.

Arise et al (2000) applied the Johansen's co-integration procedure and ECM to detect a negative effect of real exchange rate volatility on export. Quarterly data spanning from 1973 to 1996 on thirteen Less Developed Countries (LDCs) were used in the analysis. The result revealed that an increase in REER resulted in a significant negative effect on export demand in each of the thirteen (13) countries in both short and long-run. Kasman and Kasman (2005) used quarterly data spanning from 1982 to 2001 and applied co-integration and Error correction model to investigate the impact of real exchange rate volatility on Turkey's export to its major trading partners. Exchange rate volatility exhibited significant positive effect on export volume in the long-run.

Generally, empirical works that end up establishing a positive relationship between exchange rate volatility and trade flows are in tandem with the risk portfolio school of thought, which believes that, 'the higher the risk the higher the reward', therefore, the consequent risk occasioned by exchange rate volatility will only breed more trade(investment) opportunities. Studies that resulted in a significant positive relationship between exchange rate and trade variable(s) could be seen in the works of Aliyu (2010); Kasman and Kasman (2005); among others. The case of ambiguous relationship between these two variables is evident in Kumar and Whitt (1992); Arestotelous (2001); Tenreyo (2007, etc. The main contribution of this paper is to use the GARCH modeling technique combined with the ARDL bounds testing approach to examine the impact of both nominal and real exchange rate volatilities on monthly export and import volumes of Nigeria for the period, 1997M1 – 2016M12. The study would provide empirical evidence to drive policy formulation in the management of exchange rate as it impacts on trade and provide information that could guide more studies on the subject.

IV. Methodology

IV.1 Estimation Technique

The focus of the study requires that the volatility form of REER be generated. Consequently, the study employed the Generalised Autoregressive Conditional Heteroscedasticity (GARCH) model to generate the volatility series for REER. This was consistent with the studies by Pozo (1992), Kroner and Lastrapes (1993), Caporale and Doroodian (1994), Sauer and Bohara (2001), Clark et al. (2004), DeVita and Abbott (2004) and Asteriou et al. (2016) who have extensively adopted the method in modelling volatility.

Following that, the study used the generated volatile form of REER in an autoregressive distributed lag (ARDL) model (ARDL bounds test for co-integration) and ECM-based granger causality in order to estimate the short and long-run relationships and the direction of causality, respectively, among the variables. The ARDL is preferred to other methods, such as Engel and Granger (1987), Johansen (1988, 1991), Johansen-Juselius (1990) and Phillips and Hansen (1990), because it allows for a more flexible procedure that can be applied even when the variables are of different orders of integration (Pesaran and Pesaran, 1997).

The ARDL bound testing procedure uses the F-statistic for the joint significance of the estimators of the lagged levels in the model to test the null hypothesis of "no co-integration". As we cannot use the standard F-distribution, Pesaran et al. (2001) provide two asymptotic critical values: the lower value assumes that all variables are I(0) and the upper value assumes that all variables are I(1). If the calculated F-statistic is higher than the upper critical value, then the null hypothesis (no co-integration) is rejected. Alternatively, if the calculated F-statistic is below the lower bound, we conclude that there is no co-integration. However, if the F-statistic is within the respective bounds, the co-integration test is inconclusive. Once a co-integration relationship is detected, the ARDL model can be applied to investigate the long-run and the short-run relationship between the variables.

According to Narayan and Smyth (2004), the presence of co-integration only indicates the presence of a long-run relationship and the existence of causality at least in one direction. Hence, the next step after confirming the existence of a long-run relationship is to establish the direction of causality. The causal relation between exchange rate volatility and trade flows was investigated using the ECM-based approach, which has the ability to model the time path of returning to long-run equilibrium.

IV.2 Data and Variables

Nigeria's monthly time series dataset was used for the period 1997M1 to 2016M12. Export (lX_t) and import (lM_t) volume data are taken from the World Bank Development Indicators (WDI) annual database. The original annual data for Nigeria are taken from WDI and converted into monthly frequency using the "quadratic-match average" frequency conversion method[3]. To calculate the world demand condition (Y*) for Nigeria, the average of the gross domestic product of the country's 14 biggest trading partners was calculated[4]. Y* and Y (Nigeria's real GDP) were sourced from the WDI and converted into monthly frequency through the same method. Relative export and import prices (P^x and P^m) were sourced from the WDI and converted from annual to monthly series. Nigeria's monthly official and parallel market exchange rates were sourced from the Central Bank of Nigeria's (CBN) database. The variable, V_1 represents the proxy for exchange rate volatility which was included in the model to take into account the effects of exchange

[3] Following Asteriou et al. (2016)

[4] The 14 top Nigeria's trading partners over 2007 to 2016 (United States, 19.5%; India, 10.2%; China, 8.5%; Netherlands, 6.9%; Brazil, 6.4%; Spain, 5.5%; France, 4.7%; Germany, 3.9%; United Kingdom, 3.8%; South Africa, 3.1%; Japan, 2.3; Cote d'Ivoire, 2.1; Italy, 2.0; and Korea, 2.0) contributed 80.8% of total trade.

rate uncertainty, while the subscript t represent time and *l* is the logarithmic form variable. $V_t^{parallel}$ and $V_t^{official}$ represent volatility of the parallel and official exchange rates, respectively.

IV.3 Models Specification

To derive the volatile form of REER, the study followed a step by step approach involving: (i) generating REER returns series; (ii) Checking for ARCH effect on the returns; and (iii) Modelling an optimal ARCH/GARCH family-type model given that there was ARCH effect. We resound that the study did not model GARCH absolutely, but only adopted the method to make '*conditional variance',* which empirically represents the volatility series of REER. Model (1) – (4) indicate the steps followed in deriving the above:

REERR = Log (REERt / REERt-1) (1)

Where: REERR= Real Effective Exchange Rate Returns;
REERt = Current Real Effective Exchange Rate; and
REERt-1 = Real Effective Exchange Rate Lagged one period

The series generated using the process was used in a simple autoregressive mean model in order to test for the existence of an ARCH effect (AR(k)) (k=1) thus:

$$REERR_t = \alpha_0 + \alpha_1 REERR_{t-1} + \varphi_t \qquad (2)$$

Given equation 2, the next step involved regressing the square of the contemporaneous residual in equation 2 on the squares of their lagged residuals thus:

$$\hat{\varphi}^2{}_t = \eta_0 + \sum_{i=1}^{p} \eta_i \hat{\varphi}^2{}_{t-1} \qquad (3)$$

Where: $\hat{\varphi}^2{}_t$ =squared error term of the mean equation;
p = length of ARCH lags;
$i=1$ =starting from lag1 to p
$\eta_i = \eta_1$ ------ η_p = Coefficients of lagged squared error term of the mean equation

The hypothesis of the ARCH effect (H_0) is stated as: "no ARCH effect" thus:

$$H_0 : \eta_0 = \eta_1 = \ldots = \eta_p = 0$$

The process continued with measuring the extent of volatility which is a system model that combines both the mean equation and the variance equation, thus:

$$\begin{bmatrix} REERR_t = \alpha_0 + \alpha_1 REERR_{t-1} + \varphi_t \\ \varphi^2{}_t = \eta_0 + \eta_1 \varphi^2{}_{t-1} + \eta_2 \varphi^2{}_{t-2} + \eta_3 \varphi^2{}_{t-3} + \ldots + \eta_n \varphi^2{}_{t-n} + \iota_t \end{bmatrix} \qquad (4)$$

Equation 4 was used to make the '*GARCH variance*' series which represents the REER volatility used in the ARDL-ECM Framework. To empirically investigate the impact of exchange rate volatility on trade flows in Nigeria, we estimate the export supply and import demand functions adapting Arinze et al. (2000); and Asteriou et al. (2016). Equations 1 and 2 are the export functions with the respective parallel and official exchange rates volatilities, while equations 3 and 4 represent the import functions with the respective parallel and official exchange rates volatilities. The export and import functions are as follows;

$$lX_t = \delta_{10} + \delta_{11} lY_t^* + \delta_{12} lP_t^x + \delta_{13} V_t^{parallel} + \omega_{1t} \quad (5)$$

$\delta_{11} > 0$, $\delta_{12} < 0$, δ_{13} ?

$$lX_t = \delta_{20} + \delta_{21} lY_t^* + \delta_{22} lP_t^x + \delta_{23} V_t^{official} + \omega_{2t} \quad (6)$$

$\delta_{21} > 0$, $\delta_{22} < 0$, δ_{23} ?

$$lM_t = \delta_{30} + \delta_{31} lY_t + \delta_{32} lP_t^m + \delta_{33} V_t^{parallel} + \omega_{3t} \quad (7)$$

$\delta_{31} > 0$, $\delta_{32} < 0$, δ_{33} ?

$$lM_t = \delta_{40} + \delta_{41} lY_t + \delta_{42} lP_t^m + \delta_{43} V_t^{official} + \omega_{4t} \quad (8$$

$\delta_{41} > 0$, $\delta_{42} < 0$, δ_{43} ?

IV.3.1 Co-integration

Following Odhiambo (2008) and Narayan and Smyth (2008), the ARDL-bounds specification for models 1 - 4 is presented in Equations 1-16.

ARDL Model Specifications for Model 1(lX_t,lY_t^*, $V_t^{Parallel}$, and lP_t^x)

$$\Delta lX_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^* + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^x + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^* + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{1t} \quad (9)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^* + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^x + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^* + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{1t} \quad (10)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^* + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^x + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^* + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{1t} \quad (11)$$

$$\Delta V_t^{Parallel} = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^* + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^x + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^* + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{1t} \quad (12)$$

Where a_0 is a constant, a_1 - a_4 and B_1 – B_4 are regression coefficients, and U_{1t} is an error term.

ARDL Model Specifications for Model 2 (lX_t,lY_t^*, $V_t^{official}$, and lP_t^x)

$$\Delta lX_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^* + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^x + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^* + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{2t} \quad (13)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^* + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^x + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^* + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{2t} \quad (10)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^* + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^x + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^* + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{2t} \quad (14)$$

$$\Delta V_t^{Official} = a_0 + \sum_{i=1}^{n} a_1 \Delta lX_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-i}^{*} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{x} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lX_{t-1} + B_2 \Delta lY_{t-i}^{*} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{2t} \quad (15)$$

Where a_0 is a constant, a_1 - a_4 and B1 – B4 are regression coefficients, and U_{2t} is an error term.

ARDL Model Specifications for Model 3 (lM_t, lY_t, lP_t and $V_t^{Parallel}$)

$$\Delta lM_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{3t} \quad (16)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{3t} \quad (17)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{3t} \quad (18)$$

$$\Delta V_t^{Parallel} = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Parallel} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Parallel} + U_{3t} \quad (19)$$

Where a_0 is a constant, a_1 - a_4 and B1 – B4 are regression coefficients, and U_{3t} is an error term.

ARDL Model Specifications for Model 4 (lM_t, lY_t, lP_t and $V_t^{official}$)

$$\Delta lM_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{4t} \quad (20)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{4t} \quad (21)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{4t} \quad (22)$$

$$\Delta V_t^{Official} = a_0 + \sum_{i=1}^{n} a_1 \Delta lM_{t-1} + \sum_{t=0}^{n} a_2 \Delta lY_{t-1} + \sum_{t=0}^{n} a_3 \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4 \Delta V_{t-i}^{Official} + B_1 \Delta lM_{t-1} + B_2 \Delta lY_{t-1} + B_3 \Delta lP_{t-1} + B_4 \Delta V_{t-1}^{Official} + U_{4t} \quad (23)$$

Where a_0 is a constant, a_1 - a_4 and B1 – B4 are regression coefficients, and U_{4t} is an error term.

IV.3.2 A Granger-Causality Model Specification

The ECM-based Granger-causality models are specified for Models 1 to 4. According to Odhiambo (2009), the introduction of the lagged error correction term reintroduces the long-run relationship that could have been lost with differencing. It also allows analysis of causality in both the short-run and long-run.

ECM-based Granger-causality for Model 1

The ARDL Granger-causality model specification for Model 1 is given in Equations 24 – 27.

$$\Delta lX_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_1 ECM_{t-1} + U_{1t} \qquad (24)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_2 ECM_{t-1} + U_{2t} \qquad (25)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_3 ECM_{t-1} + U_{3t} \qquad (26)$$

$$\Delta V^{Parallel}_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_4 ECM_{t-1} + U_{4t} \qquad (27)$$

Where a_0 is a constant, a_1 - a_4 and θ_1 – θ_4 are regression coefficients, and $U_{1t} - U_{4t}$ is an error term.

ECM-based Granger-causality for Model 2

The ARDL Granger-causality model specification for Model 2 is given in Equations

$$\Delta lX_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Official}_{t-i} + \theta_1 ECM_{t-1} + U_{1t} \qquad (28)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Official}_{t-i} + \theta_2 ECM_{t-1} + U_{1t} \qquad (29)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Official}_{t-i} + \theta_3 ECM_{t-1} + U_{1t} \qquad (30)$$

$$\Delta V^{Official}_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lX_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY^{*}_{t-i} + \sum_{t=0}^{n} a_3\, \Delta lP^{x}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Official}_{t-i} + \theta_4 ECM_{t-1} + U_{1t} \qquad (31)$$

Where a_0 is a constant, a_1 - a_4 and θ_1 – θ_4 are regression coefficients, and $U_{1t} - U_{4t}$ is an error term.

ECM-based Granger-causality for Model 3

The ARDL Granger-causality model specification for Model 3 is given in Equations

$$\Delta lM_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP^{m}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_1 ECM_{t-1} + U_{1t} \qquad (31)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP^{m}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_2 ECM_{t-1} + U_{2t} \qquad (33)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP^{m}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_3 ECM_{t-1} + U_{3t} \qquad (34)$$

$$\Delta V^{Parallel}_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP^{m}_{t-i} + \sum_{t=0}^{n} a_4\, \Delta V^{Parallel}_{t-i} + \theta_4 ECM_{t-1} + U_{4t} \qquad (35)$$

Where a_0 is a constant, a_1 - a_4 and θ_1 – θ_4 are regression coefficients, and $U_{1t} - U_{4t}$ is an error term.

ECM-based Granger-causality for Model 4

The ARDL Granger-causality model specification for Model 4 is given in Equations

$$\Delta lM_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4\, \Delta V_{t-i}^{Official} + \theta_1 ECM_{t-1} + U_{1t} \quad (36)$$

$$\Delta lY_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4\, \Delta V_{t-i}^{Official} + \theta_2 ECM_{t-1} + U_{2t} \quad (37)$$

$$\Delta lP_t = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4\, \Delta V_{t-i}^{Official} + \theta_3 ECM_{t-1} + U_{3t} \quad (38)$$

$$\Delta V_t^{Official} = a_0 + \sum_{i=1}^{n} a_1\, \Delta lM_{t-1} + \sum_{t=0}^{n} a_2\, \Delta lY_{t-1} + \sum_{t=0}^{n} a_3\, \Delta lP_{t-i}^{m} + \sum_{t=0}^{n} a_4\, \Delta V_{t-i}^{Official} + \theta_4 ECM_{t-1} + U_{4t} \quad (39)$$

Where a_0 is a constant, a_1 - a_4 and $\theta_1 – \theta_4$ are regression coefficients, and $U_{1t} - U_{4t}$ are an error term.

V. Empirical Analysis and Discussion of Results

V.1 Empirical Analysis

In carrying out the empirical analysis, we first generate the volatility series using GARCH model (the different measures of exchange rate volatility are depicted in the table 1). We affirm the appropriateness of the GARCH model by carrying out serial correlation and heteroscedasticity tests since univariate volatility model is only valid if there is presence of serial correlation and ARCH effects. Second, we employ the ARDL bounds testing approach in order to test the existence or absence of long-run relationship between exchange rate volatility and trade flows. Third, since ARDL doesn't determine the direction of causality, we estimate an error correction model (ECM) i.e. the short-run dynamic parameters associated with the long-run estimates.

V.2 Discussion of Results

Two pre-steps are followed in applying the GARCH models to capture the volatility of exchange rates. First, GARCH modeling requires the data to be stationary. Thus, the augmented Dicker-Fuller (ADF) test was used as presented in Table 1. Here, LOFF and LPAR represent the logarithm forms of official and parallel market exchange rates. The results in Table 1 suggest that LOFF and LPAR are level stationary. Second, we identify the appropriate ARIMA models to be fitted to both LOFF and LPAR.

Table 1: ADF result for the variables

Variable	Level
LOFF	-5.334**
LPAR	-4.471*

**Significance at 1%, * Significance at 5%

Table 2 presents the results from the Breusch-Godfrey serial correlation and ARCH-LM heteroscedasticity tests of the nominal and real exchange rates. The Schwartz (SIC) and Akaike (AIC) information criteria were used as model selection tools. The model that gave the minimum AIC and SIC values was chosen. Univariate volatility model is only valid if there is presence of serial correlation and ARCH effects[5]. As such we are expected to reject the null hypothesis of no heteroscedasticity and no serial correlation for the univariate volatility framework to be valid for analyses. Based on the results, serial correlation and ARCH effects were only detected for parallel exchange rate as we reject the null hypothesis of no serial correlation and no heteroscedasticity.

Table 2: Fitted ARIMA (p,d,q) models

	LOFF	LPAR
AR(1)	0.9986 (0.0000)	0.9979 (0.0000)
C	4.0705 (0.0383)	4.3068
(p,d,q)	1,0,0	1,0,0
B-G LM Test	0.1103	0.0000
ARCH-LM Test	0.9831	0.0000

Note: (a) p values are presented for the tests and in parenthesis; (b) null hypothesis for Breusch-Godfrey serial correlation test: No serial correlation; (c) null hypothesis for ARCH-LM heteroscedasticity test: No ARCH effect.

The GARCH model is therefore estimated for LPAR and used to predict the volatility in the exchange rate. The results are presented in Table 3 and optimum lag lengths are determined by SIC.

Table 3: Fitted GARCH (p, q) models for LPAR

	LPAR
AR(1)	0.9979 (0.0000)
C	4.3068
(p,q)	1,1
resid(-1)^2	0.3092 (0.0000)
Garch (-1)	0.6523 (0.0000)
Constant	0.0685 (0.0000)
ARCH-LM Test	0.7212

Note: (a) p-values in parentheses; (b) null hypothesis for ARCH-LM heteroscedasticity test: No ARCH effect; (c) p values are presented for the tests.

After obtaining the volatility series, we carry out the graphical and summary statistics of the distribution of the series before conducting the stationarity test. Summary statistics presented in Figure 1 at the appendix show that V_t^{par} averaged 0.002 during the review period and spread between 0.0007 and 0.019, suggesting volatility during the review

[5] Afees A. Salisu: Estimation procedure for univariate volatility modeling

period. LEV and LIV averaged 4.38 and 3.94, respectively. Following jarque-bera statistic, which is a test statistic for normal distribution, we find that all variables used are normal. Also, the result showed that all the variables except LIV, LGDP and V_t^{par} are negatively skewed. Kurtosis which is a measure of the peakedness (leptokurtic) or flatness (platykurtic) of the distribution of the series relative to the normal (3), revealed that all but the volatility series are leptokurtic.

The stationarity for all variables used in models (1) to (4) was conducted employing ADF unit root tests. The results as presented in Table 4 suggest that while domestic demand, world demands, and the volatility series are stationary in levels, other variables are stationary in first-difference form. In other words, lX_t, lP_t^x, and lM_t are I(1) while V_t^{par}, lY_t^* and lY_t are I(0).

Table 4: ADF Results for the Variables

Variables	Level	First Difference
Export volume	-3.9500 (3)	7.4209**(2)
Import volume	-3.2522 (14)	-5.7234**(13)
Domestic demand	-6.2253** (14)	
World demand	-2.3510**(14)	
Export prices	-4.4169 (4)	-7.4305**(11)
Import prices	-4.6429 (14)	-6.9640**(13)
Volatility PAR	-7.7804**(2)	

Note: Lag lengths are presented in parenthesis and determined by SIC. **Significance at 1%

The unit root test results presented in Table 4 indicate that while some variables are stationary in levels, others are stationary in first difference. Therefore, the autoregressive distributed lag (ADRL) bounds test to co-integration which allows the incorporation of I(0) and I(1) variables in the same estimation is the best approach for our empirical analysis. In employing the ARDL model, we first obtain the optimal lag orders on the first differenced variables by using the Schwartz Criterion (SIC) from the unrestricted models. Second, we use the bounds test to investigate the long-run relationship among the variables. The results of the bounds F-test are presented in Table 5 with import and export volumes as dependent variables.

Table 5: Bound Test Results (Dependent Variable, Import Volume)

Variable	F-Statistic	Lower critical value (2.5%)	Upper critical value (2.5%)	Volatility Measure
Import volume	5.26	3.69	4.89	PAR
Export volume	4.68	3.23	4.35	PAR

Note: Unrestricted intercept and no trend. Bound test critical values are taken from Pesaran et al. (2001).

All F-values are above the upper critical value, which implies that there are unique co-integration vectors for all models. In other words, we strongly reject the null hypothesis of no long-run relationship. The co-integration relationship between the variables is also justified by the error correction terms (ECT). The results in Table 6 show that all error correction terms are negative, less than one and statistically significant as required. The ECT represents the speed of recovery to long-run equilibrium. In the export supply function, ECT – 0.03 means that any deviation from the long-run equilibrium is recovered in 33.3 months (1/0.03). In the same vein, ECT – 0.3 in the import demand function reveals that any deviation from the long-run equilibrium is recovered in 3.3 months (1/0.3). These results show that while the long-run equilibrium among variables is stable in the two models, they are corrected in a relatively shorter period of time in the import demand function.

Table 6: ARDL-ECM results

Model 1	Model 2
- 0.03(0.00)**	-0.3**(0.00)

Model 1: Export demand function for exchange rate volatility
Model 2: Import demand function for exchange rate volatility
Note: (a) p values in parenthesis; (b) only the error correction terms are reported

We can also detect co-integration from the long-run estimates. Results from the export and import demand functions are presented in Tables 7 and 8, respectively. In the export demand function, world income was positive and significant while the estimated coefficients for exchange rate volatility and export price were insignificant in the long-run. This is because crude oil remains Nigeria's dominant export and as a member of OPEC, Nigeria's production volume is capped by the international organisation. As such in the long-run, exchange rate volatility and export price may not impact on Nigeria's export volume. It is not surprising that world income is positive and particularly important in Nigeria's export demand function because higher world income means higher export demand. In the import function, domestic income was positive and significant while the estimated coefficients for exchange rate volatility and import price were insignificant in the long-run. This implies that exchange rate volatility does not have any significant impact on Nigeria's trade flows in the long-run, but it does have a negative impact in the short-run.

Table 7: ARDL Estimates for Export Supply Function

Volatility measure(4,1,0,1)	V_t^{par}	lY_t^*	lP_t^x	lX_{t-1}
Short-run	-1.071 7(0.0719)	1.1390**(0.0151)	0.0007(0.8244)	0.2658**(0.0000)
Long-run	-6.0663(0.4829)	0.6383**(0.0000)	0.0218(0.8240)	

Note: (a) p values in parenthesis; **Significance at 1%, and * Significance at 5%

Table 8: ARDL estimates for import demand function

Volatility measure(4,0,4,1)	V_t^{par}	lY_t	lM_{t-1}	lP_t^m
Short-run	- 1.9337**(0.0074)	0.0391**(0.0000)	0.2163**(0.0001)	0.7527**(0.0000)
Long-run	-2.5185 (0.8264)	1.2746**(0.0000)		0.0640 (0.7638)

Note: (a) p values in parenthesis; **Significance at 1%, and * Significance at 5%

Table 9: Granger causality test results

Null Hypothesis	*F statistics*	Probability
V_t^{par} does not Granger cause lX_t	1.7736	0.1043
lX_t does not Granger cause V_t^{par}	4.1279**	0.0005
V_t^{par} does not Granger cause lM_t	1.8173	0.0955
lM_t does not Granger cause V_t^{par}	0.5758	0.7495

Note: (a) p values in parenthesis; **Significance at 1%

Having established that there is a long-run relationship between variables, the next step is to detect the causality between the variables of interest. Following Granger (1988) when a pair of 1(1) series is co-integrated, there must be causation in at least one direction. The findings of Granger causality test is given in Table 9. The Granger causality test was applied only on Models 2 and 4. Results for model 2 show that nominal exchange rate volatility is caused by export volume. This is because crude oil and gas export account for more than 95 per cent of Nigeria's foreign exchange revenue and the demand for oil is determined by international market conditions. Therefore, the causality is from lX_t to V_t^{par}, but not from V_t^{par} to lX_t. This is consistent with the results of Umaru et al. (2013) and Asteriou et al., (2016). However, results from model 4 show that nominal exchange rate volatility does not Granger cause import volume. This indicates the import-dependent nature of Nigeria's economy. Oyovwi (2012) examined exchange rate volatility and imports in Nigeria. In line with our result, he found that exchange rate volatility did not significantly explain imports.

VI. Conclusion and Policy Recommendations

Given that the primary source of foreign exchange earnings in Nigeria has been the export of crude oil with the attendant volatility in its price, investigating the impact of exchange rate volatility on trade flows is timely and of policy relevance. We tested the impact of exchange rate volatility on export and import demand for Nigeria for the period 1997 – 2016 using monthly data. We used GARCH model to generate nominal exchange rate volatility series. To detect the long-run relationship among variables, the ARDL bounds testing approach was employed, and the Granger causality test was applied to investigate the short-run behaviour of the variables. In the short-run, we find that volatility negatively affect Nigeria's trade flows, but does not in the long-run. As such the Central Bank of Nigeria would find some trade benefits from intervening immediately to stabilise the foreign exchange market in the face of exchange rate shock or volatility (sterilised foreign exchange intervention used to limit exchange rate volatility (Daude et al., 2014).

Also, the study has shown that ignoring the unexpected effects of exchange rate shocks could negatively impact on Nigeria's trade flows especially in the short-run. As such the monetary authority should consistently pursue policies that would ensure stability of the exchange rate. The empirical results are limited to some extent as the lowest frequency of the data used was monthly. Also the conversion of some variables from annual to monthly might affect the quality of the results. Moreover, there are important improvements to the GARCH approach, which was used to generate the volatility series, such as multivariate GARCH, switching regime GARCH (SWARCH), asymmetric extension of GARCH or exponential GARCH (EGARCH) models. Future research might concentrate on which GARCH model best capture the impact of exchange rate on trade flows in Nigeria.

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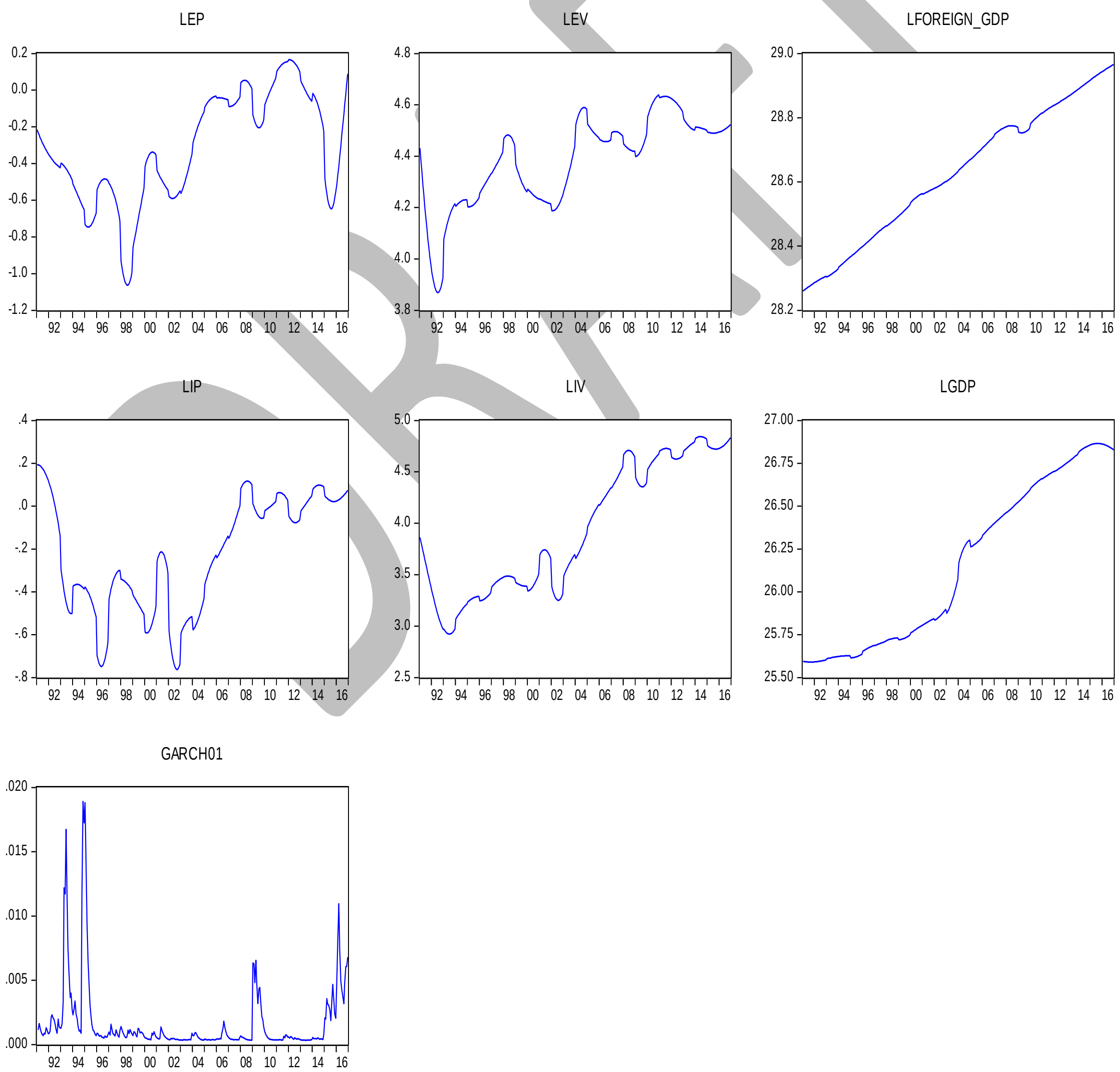
Appendix 1
Summary Statistics

	LEP	LEV	LFOR_GDP	LIP	LIV	LGDP	$V_t^{parallel}$
Mean	-0.318633	4.380279	28.62761	-0.226215	3.938357	26.15791	0.001668
Median	-0.345333	4.427759	28.63614	-0.218780	3.738293	26.16915	0.000661
Maximum	0.166173	4.638621	28.96542	0.193251	4.842508	26.86579	0.018903
Minimum	-1.063192	3.868539	28.26193	-0.762845	2.922662	25.59067	0.000326
Std. Dev.	0.299546	0.175831	0.207201	0.264873	0.635330	0.470962	0.002812
Skewness	-0.283565	-0.772702	-0.145422	-0.281438	0.088519	0.185030	3.754728
Kurtosis	2.341999	3.283610	1.794704	1.837095	1.421709	1.394387	18.97102
Jarque-Bera	9.778390	31.99035	19.92121	21.62976	32.68539	35.18106	4036.073
Probability	0.007527	0.000000	0.000047	0.000020	0.000000	0.000000	0.000000
Sum	-99.09481	1362.267	8903.185	-70.35301	1224.829	8135.110	0.518726
Sum Sq. Dev.	27.81557	9.584103	13.30906	21.74887	125.1298	68.75961	0.002452
Observations	311	311	311	311	311	311	311



Appendix 2
Measures of Exchange Rate Volatility

	Measures of exchange rate volatility (V)	**Used as a primary measure of volatility in:**
1	Absolute percentage change of the exchange rate, i.e. $V_t = \|(e_t - e_t - 1)\|/e_t - 1$ Where e is the spot exchange rate and t refers to time.	Thursby and Thursby (1985) Bailey, Tavlas and Ulan (1986)
2	Average absolute difference between the previous forward and the current spot rate, i.e. $V_t = \sum_{i=1}^{n} \|f_{t-1} - e_t\| / n$ Where f is forward rate.	Hooper and Kohlhagen(1978)
3	Variance of the spot exchange rate around its trend which is predicted from $(In\ e_t = \emptyset_0 + \emptyset_1 t + \emptyset_2 t^2 + \mathcal{E}_t)$	Thursby and Thursby (1987)
4	Moving average of the standard deviation of the exchange rate. For example, as used by Koray and Lastrapes (1989) $v_t = \left[(1\|m) . \sum_{i=1}^{m} (Z_{t+i-1} - Z_{t+i-2})^2\right]^{1/2}$ Where Z is the long relative price of foreign consumer goods in terms of US consumer goods and m=12	Cushman(1983), (1986) and (1988a,b) Akhtar and Spence-Hilton(1984) Gotur(1985) Kenen and Rodrik (1986) Bailey Tavlas and Ulan(1987) Caballero and Corbo (1989) Korey and Lastrapes(1989) Klein (1990) Bini- Smaghi (1991) Kumar and Dhawan (1991) Chowdhury (1993)
5	Long-run exchange rate uncertainty, measured as : $v_t = \frac{max\, X_{t-k}^t - min\, X_{t-k}^t}{\min X_{t-k}^t} + \left[1 + \frac{\|X_t - X_t^p\|}{X^p}\right]^2$ Where X_t is the nominal exchange rate time t, $max\, X_{t-k}^t$ and $min\, X_{t-k}^t$refers to maximum and minimum values of the nominal exchange rate over a given time interval of size k up to the time t, and $X_t^p$is the equilibrium exchange rate.	Peree and Steinherr (1989)
6	Standard deviation of the yearly percentage changes of a bilateral exchange rate around the mean observed during the subperiod	De Grauwe and Bellefroid (1986) De Grauwe(1987) De Grauwe(1988)
7	ARIMA model residuals	Asseery and Peel (1991) McIvor (1995)
8	Non Parametric Technique	Belanger et al. (1992)
9	ARCH models	Poza (1992) Kroner and Lastrapes (1993) Caporale and Doroodian(1994) Qian and Varangis (1994) Mckenzie and Brooks (1997) Mckenzie(1998)

Source: M.D., M. (1999). The Impact of Exchange Rate Volatility on International Trade Flow