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**Article**

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West African Journal of Monetary and Economic Integration

**Provided in Cooperation with:**

West African Monetary Institute (WAMI), Accra

*Suggested Citation:* Bawa, Sani; Abdul, Rabia Muhammad; Sani, Zainab; Dauda, Mohammed (2018) : Testing the J-curve phenomenon in Nigeria: An ARDL bounds testing approach, West African Journal of Monetary and Economic Integration, ISSN 0855-594X, West African Monetary Institute (WAMI), Accra, Vol. 18, Iss. 1, pp. 47-71

This Version is available at:

<https://hdl.handle.net/10419/264249>

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# TESTING THE J-CURVE PHENOMENON IN NIGERIA: AN ARDL BOUNDS TESTING APPROACH<sup>1</sup>

*Sani Bawa, Rabia Muhammad Abdul, Zainab Sani and Mohammed Danda<sup>2</sup>*

## **Abstract**

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*This study examined the short-run and long-run effects of real exchange rate changes on the Nigeria's trade balance. The paper employed both linear and non-linear ARDL bounds testing approach to cointegration to test for the J-curve phenomenon in Nigeria using quarterly data spanning the period 1994 to 2018. Empirical results from the analysis revealed that real depreciation would lead to improvements in Nigeria's trade balance in the long-run. It also indicated that growth in foreign income tend to worsen the trade balance, while growth in domestic income improved the Nigeria's trade balance. In the short-run, however, our findings revealed that the J-curve phenomenon does not hold in Nigeria. The non-linear model result further provided additional evidence that the impact of real exchange rate changes on trade balance in Nigeria is asymmetric, as real depreciation played a significant role in influencing Nigeria's trade balance, while real appreciation does not have an impact. The study recommends a moderation in imports through an expansion in domestic production and the need to encourage non-oil exports in the country.*

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**Keywords:** Real Exchange Rate, Trade Balance, J-Curve, Depreciation

**JEL Classification:** C22, F14, F31

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<sup>1</sup>The views expressed in this paper are those of the authors and do not represent the position of the Central Bank of Nigeria (CBN) or West African Monetary Institute (WAMI).

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## 1.0 INTRODUCTION

Traditional economic theory has shown that there is relationship between changes in a country's real exchange rate (appreciation or depreciation) and its trade balance. A depreciating exchange rate would lead to lower foreign prices of a country's exports, thereby stimulating demand of its goods by foreign consumers because such goods would be relatively cheaper than the domestic goods of the foreign consumers. Similarly, depreciation raises the domestic prices of imports, making imports more expensive, thereby decreasing the domestic demand for imports<sup>3</sup>. The expansion in exports emanating from the increase in foreign demand, and the fall in imports as a result of decreasing domestic demand are expected to lead to improvements in a country's trade balance.

Countries across the world often devalue/depreciate their national currency in an attempt to improve their trade balance in line with this proposition. The effectiveness of devaluation/depreciation in improving a country's trade balance, however, depends on whether the Marshall-Lerner condition holds. The Marshall-Lerner condition states that exchange rate devaluation or depreciation would only lead to improvement in the trade balance if the absolute sum of export and import price elasticities exceeds unity.

Magee (1973), however, noticed the deterioration in US trade balance in 1972 despite the devaluation of the US dollar in 1971 and the satisfaction of the Marshall-Lerner condition by the US. He therefore argued that the short-run effects of devaluation/depreciation could be distinguished from its long-run response, as a country's trade balance tends to deteriorate in the short-run before recording improvements in the long-run. This situation follows a pattern of movement that resemble the letter J, giving rise to the J-Curve phenomenon. Magee (1973) attributed the occurrence of the J-curve phenomenon in the US to two major factors: first, the rapid increase in domestic activities (real income) in the US relative to foreign industrial activities in 1972, which swamped any effects that the devaluation might have generated; and second, the expansion in exports and the contraction in imports occurred only after substantial lags.

Junz and Rhomberg (1973) identified at least five lags that influence the relationship between changes in exchange rates and their ultimate effects on real trade. They included some lags in their model to represent the dynamics of the exchange rate market and capture the impact of replacement decisions of inventories and other resources used in the production process. However, Krueger (1983) noted that change in exchange rate when the goods have been purchased and are on their way outside the country thus the purchase contract has been entered into hence such transaction cause the noticeable change in the current account balance in the short-term. Magee (1973) termed it the 'currency contract period' when contracts already in force in specified currencies dominate the determinants of the current account. Overtime, new contracts made after the exchange rate changes begin to dominate, and the pass-through of the devaluation or depreciation begin to manifest.

The core objectives of exchange rate policy is to protect the value of a country's currency, maintain a favourable external reserves position as well as safeguard external balance without negating the overriding objective of a stable macro-economy. Accordingly, Nigeria has adopted various exchange rate regimes over the years in order to achieve these objectives. Since the replacement of the British pound with the Naira in 1973, the latter have witnessed fluctuations culminating in its devaluation or depreciation over the period. Similarly, the country's trade balance, which witnessed deficits in 1960s and early 1970s owing to the import of capital goods to stimulate industrial development, reversed to record surpluses afterwards occasioned by improved export earnings from crude oil and natural gas.

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<sup>3</sup> See Alexander (1959) for more on this Relationship.

A number of studies have confirmed the satisfaction of the Marshall-Lerner condition using Nigeria's real exchange rates and trade balance data. For instance, Igue and Ogunleye (2014) and Sulaimon, Omotunde and Haorayah (2017) found the sum of price elasticities from the export and import demand functions to be 1.6, indicating that depreciation of the Naira exchange rate could improve Nigeria's trade balance in the long-run. Given this, empirical works were conducted to validate the J-curve phenomenon in Nigeria, and they include Douglason (2009) for the trade balance for Nigerian agricultural products and Umoru and Eboeime (2013) for the oil sector.

Baba and Yazici (2016), however, examined the J-curve phenomenon in Nigeria's trade balance with 15 European Union (EU15) countries. The main drawback of most empirical studies validating the J-curve in Nigeria is that they assumed that the relationship between real exchange rates and trade balance is linear. However, Bahmani-Oskooee and Fariditavana (2016) show that the relationship could be non-linear and adopting a non-linear adjustment process could help in determining whether the short-run and long-run effects of real exchange rate changes on the trade balance are symmetric or asymmetric. Even though Umoru and Oseme (2013) utilized a non-linear approach by testing the phenomenon using the vector error correction methodology (VECM), the Autoregressive Distributed Lag (ARDL) Bounds Testing approach to cointegration was found to be more suitable for investigating the response of trade balance to exchange rate depreciation (Bahmani-Oskooee and Hegerty, 2010).

Considering the dearth of studies utilizing the non-linear ARDL approach in the Nigeria context, this study seeks to investigate the relationship between real exchange rates and Nigeria's trade balance. The main objective of the study is to examine whether the J-curve phenomenon holds in Nigeria. The study applied both linear and non-linear Autoregressive Distributed Lag (ARDL) Bounds Testing approach to cointegration. The non-linear specification accounts for non-linearities in the movement of the variables, and would enable us separate the effects of Naira exchange rate appreciations and depreciations on Nigeria's trade balance.

The paper is structured into six sections. Following this introduction is section two which examine the literature review and theoretical issues while section three presents an overview of exchange rate regimes and Nigeria's trade balance. Section four contains the econometric model specification, estimation procedure and data sources. Further, section five presents the empirical results along with the discussions on findings, whereas section six concludes the study and provides some policy prescriptions.

## **2.0 LITERATURE REVIEW AND THEORETICAL ISSUES**

### **2.1 Theoretical Issues**

Igue and Ogunleye (2014) indicated that it is important to understand the response of trade balance to exchange rate movements to ensure the effective coordination and implementation of trade and exchange rate policies. In addition, it helps countries avoid persistent deficits in their trade balance, thereby avoiding financial crises emanating from it. The relationship between exchange rate devaluation/depreciation and trade balance has been extensively discussed in three main theories – elasticity approach, absorption approach and the monetary approach.

The elasticity approach to balance of payments was encapsulated in the seminal papers of Bickerdike (1920), Robinson (1947) and Metzler (1948), culminating in Bickerdike-Robinson-Metzler (BRM) model. The basic idea of this approach lies in the substitution effects in consumption and production often arising from relative price changes caused by exchange rate movements. The BRM model is a partial equilibrium model widely recognized as providing a sufficient condition for exchange rate devaluation/depreciation and improvement in trade balance.

The absorption approach originates with the work of Alexander (1952) which defined trade balance as “the difference between aggregate domestic income and domestic expenditure”, thus, moving away

from the initial assertion that trade balance is the difference between the exports and imports of a country. The model combines both the elasticities approach and the Keynesian macroeconomics using underlying conjecture that categorizes country's expenditure into four elements– Consumption (C), Investment (I), Government Expenditures (G), and imports (M). Central to this approach is the proposition that an improvement in a country's trade balance requires an increase in aggregate income over expenditures. The approach analyses the effects of exchange rate changes on relative prices, income and domestic absorption as well as the trade balance.

The monetary approach analyses trade balance from the point of view of the demand and supply of money. The approach opined that if the demand for money in a country outweighs its supply, then the excess demand for money would be satisfied through foreign sources and this would result in a positive trade balance. However, excess supply of money would lead to outflow of money from the economy, resulting in a negative trade balance. The core of this approach is that excess supply of money by the central bank has a detrimental effect on trade balance, and a country can improve its trade balance by decreasing the supply of money in the economy.

The Marshall-Lerner (ML) condition, which is an offshoot of the elasticity approach, extended the typical trade theory by examining the elasticity of the demand for imports and exports in measuring the effect of real exchange rate variations on trade balance. The model argued that rising exports and fall in imports arising from real exchange rate depreciation would improve the trade deficit. The ML condition states that “the depreciation of a country's currency would improve its trade balance in the long-run if the sum of absolute values of its export and import demand elasticities is greater than unity.” However, depreciation would worsen the trade balance if the sum is less than unity.

The J-Curve model, on its part, postulates that a country's trade balance often worsens in the short run before witnessing improvements in the long run in line with ML condition. A number of factors contribute to the J-curve phenomenon (Bahmani-Oskooee, 2008). First, commodities in transit are priced at the old exchange rate. If the trade balance had been deteriorating before exchange rate depreciation, it will continue to deteriorate after the depreciation. Only after the passage of some time when new prices begin to prevail at the new exchange rate will the trade balance improve. Second, at the time of depreciation, a country could experience a rapid increase in its national output, leading to economic growth. Since a growing economy consumes more of not only domestically produced goods but also of imported goods, its imports could rise substantially. The increase in imports may offset any favourable effects of depreciation, resulting in a short-run deterioration of the trade balance. Finally, depreciation is expected to increase the volume of exports and reduce the volume of imports. However, the adjustment of export and import volumes to exchange rate changes may occur with some adjustment lags. These could include lags in delivery time, lags in replacing inventories, and lags in adjusting the production process.

## 2.2 Literature Review

Magee (1973) study of the J-curve effect in the US showed that in spite of the 1971 devaluation of the US dollar, its trade balance significantly dropped in 1972 largely due to the effect of the J-curve Phenomena. Following this, Bahmani-Oskooee (1985) examined the effect of the J-curve in Thailand, India, Greece, and Korea. Findings from the study showed that trade balances declined in Greece, Korea and India after currency devaluation and linger for quite some time before it begins to improve. Since then, a number of studies were undertaken to empirically validate the J-curve phenomenon utilizing either the ordinary least squares (OLS), linear Autoregressive Distributive Lag (ARDL) or the error correction methodology (ECM) techniques.

Rose and Yellen (1989) examine the J-curve phenomenon utilizing US data for twenty five years. The study couldn't detect any short-run deterioration in US merchandise trade balance in response to real exchange rate depreciations using both US bilateral trade and aggregate trade data. The study attributed the divergence in their results with conventional findings to two factors – the utilization of a non-stationarity time series data; and the probable simultaneity of the balance of trade, exchange rates and output. The authors showed that there is little evidence of a J-curve when these factors are accounted for in real exchange rate and trade balance analysis. Similarly, Bahmani-Oskooee and Alse (1994) conduct a study of 22 developing and 19 developed economies taking into account the probable simultaneity and non-stationarity of the time series data. The study establish that trade balance and the real effective exchange rates were cointegrated in only 6 countries. The analysis confirm that devaluation could not have any long run effects on trade balance in the other countries. However, the study provide evidence of the J-curve phenomenon prevailing in the 6 countries.

Bahmani-Oskooee and Brooks (1999) utilize a disaggregated trade data of the US and six (6) of its major trading countries to examine the effect of currency devaluation on the balance of trade using the ARDL approach to cointegration. Findings from the study did not indicate a particular pattern in the short-run thus rejecting the J-curve hypothesis. However, the long run results show a positive relationship as the US trade balance improved in the face of currency devaluation. This result is consistent with similar findings in Rose and Yellen (1989) study of the US. In a similar study, Gupta-Kapoor and Ramakrishnan (1999) employ quarterly data of Japan from 1975 - 1996 to examine the validity of J-curve theory using impulse response functions (IRF) derived from a VAR technique. Results from the IRF analysis indicate a short-run deterioration in trade balance lasting for about a year in response to an exchange rate movement, implying that the J-curve phenomenon holds for Japan during the period.

Bahmani-Oskooee and Kantipong (2001) adopt a two-country model of trade as in Rose and Yellen (1989) and the ARDL approach in a study of Thailand and its five (5) major trading partners that include Japan, Singapore, Germany, United Kingdom (UK) and United States (US). They find that J-curve phenomenon only exist between Thailand, US and Japan, as in the short-run, currency depreciation led to a fall in its balance of trade balance, but appreciated in the long-run.

On their part, Lal, and Lowinger (2002) utilize the cointegration and error correction models as well as IRFs to analyse the key determinants of trade balances in seven East Asian economies that include Indonesia, Japan, Korea, Malaysia, Philippines, Singapore and Thailand. Their empirical results show that the devaluation of currency in six (6) countries initially led to worsening balance of trade and later appreciated thus suggesting a long-run effect. The results also uncover variations in duration and the size of the J-curve effects over some countries which perhaps may be due to differences in their trade policies and exchange rate. Equally, Onafowora (2003) use the VAR model to investigate the impact of real exchange rate and the balance of trade in Thailand, Indonesia and Malaysia with Japan and US. They find evidence of long-run Marshall-Lerner condition across the samples countries. On the other hand, short-run J-curve effects were also found in Malaysia and Indonesia's trade relations with Japan and US. Similar result were obtained in the trade relations between US and Thailand while an S-curve phenomenon was found in Japan and Thailand's trade relations.

Using a disaggregated approach, Bahmani-Oskooee and Goswami (2003) examines Japan's trade relations with nine (9) of its major partners. They found J-curve impact on German and Japan trade rations as well as between Italy and Japan. Similarly, Bahmani-Oskooee and Ratha (2004) show that J-curve phenomenon was visible in the bilateral trade between the US and 4 developing countries during 1975 to 2000, out of the 13 developing countries' bilateral trade data employed in the study. Furthermore, Bahmani-Oskooee and Ratha (2007) ARDL model shows that in the short-run, J-curve effect exist in the trade balance of Sweden and five (5) of the sampled trading partners examined in the period between 1980 and 2005. On the other hand, Bahmani-Oskooee and Harvey (2009) study of

Indonesia in the period 1975 – 2008 found evidence of the J-curve effect in five (5) of its 13 bilateral trading partners.

Baek, Koo and Mulik (2009) also utilize the ARDL approach to study the effect of exchange rate devaluation on agricultural trade of US and fifteen of its major trading partners. The study however, did not establish the impact of a J-curve which they explained was due to the fact that the short-run response of the trade balance to US dollar depreciation did not respond to any discernible pattern. However, the long-run effects was consistent with theoretical relationship between exchange rates and trade balance.

Khattoon and Rahman (2009) use annual data of Bangladesh for the period 1972 – 2006 to study the relationship between currency devaluation and trade balance. They discover a positive relationship both in the short-run and long-run although did not trace a J-curve phenomena. However, Aziz (2012) finds that the J-curve hypothesis holds for Bangladesh using results from impulse response functions and quarterly data for 1980 to 2009.

Dash and Narasimhan (2011) study use monthly series for the period 1993 – 2005 and employ the Generalized Impulse Response Function (GIRF) and Vector Error Correction methods (VECM) to examine India's balance of trade with eleven of its major trading partners and found evidence of a delayed J-curve effect. According to the authors, India's trade balance witnessed improvements in the first four months following a depreciation of its currency, deteriorates for the next two months and experienced improvements again thereafter. In a similar study, Dash (2013) study established the presence of J-curve effects in India's trade relations with Germany and Japan. The study reveal deficits in India's balance of trade in the first two months and surplus thereafter anytime the Indian Rupee depreciate however, the study could not find a J-curve effect in their UK/US trade relations.

Utilizing the ARDL bounds testing approach to cointegration, Kyophilavong, Shahbaz and Uddin (2013) establish a short-run negative influence of currency devaluation on trade balance in Laos particularly when a lagged value of exchange rate is used. Additional results from GIRF analysis also confirm the presence of the J-curve effect in Laos. Chaulagai (2015) empirically tests the J-curve hypothesis using Nepalese trade data for the period 1975 – 2013. However, the study could not find any evidence of J-curve in Nepal, thus implying that Nepal balance of trade does not appreciate even if its currency depreciates. In the same vein, Tunaer Vural (2016) use monthly disaggregated trade data of Turkey and Germany for the period 2002 – 2014 to examine the presence or otherwise, of a J-curve phenomenon. Empirical results from the bounds test approach to cointegration analysis provided support for the existence of J-curve effects in 20 out of 96 commodity groups.

In African countries, Bahmani-Oskooee and Gelan (2012) utilize quarterly data of nine African countries including among others Nigeria, Sierra Leone, South Africa, Egypt, Kenya, and Mauritius from 1971 – 2008 to determine the presence of the J-curve hypothesis. The study use Error Correction Model (ECM) and bounds testing approach and could not establish a short-run J-curve phenomenon in all the countries. They however, found a long run effect of exchange rate depreciation on trade balance in Nigeria, South Africa, and Egypt.

In a similar study on South Africa, Schaling and Kabundi (2014) find evidence supporting the J-curve hypothesis in the short-run in South Africa utilizing quarterly data for 1994 to 2011. They also shows that net exports are boosted by a weaker real effective exchange rate of the South African Rand in the long run. However, Ziramba and Chifamba (2014) study using bounds test methods on South Africa's annual aggregate trade data for the period 1975 – 2011 did not find any evidence of the J-curve phenomenon.

Studies on Nigeria also abounds in the empirical literature. Douglasson (2009) tests the J-curve phenomenon on Nigeria's agricultural trade balance for the period 1970 – 2006. Results from the paper indicate that the J-curve does not hold in the agricultural sector in Nigeria during the period, and the relationship largely reflected an S-curve. Similarly, Umoru and Eboreime (2013) could not find any evidence of a J-curve phenomenon in the Nigerian oil sector utilizing the ARDL approach and annual data for 1975 to 2009. Furthermore, Umoru and Oseme (2013) have shown that the J-curve effect does not hold in Nigeria, as real exchange rate shocks initially improves the country's aggregate trade balance; worsen it thereafter before recording improvements again. Igue and Ogenleye (2014) study have shown evidence of the impact of currency devaluation on balance of trade in Nigeria in the long-run in line with the Marshall-Lerner condition. However, their short-run VECM results did not prove the presence of a J-curve effect in Nigeria.

Baba and Yazici (2016) also examine the J-curve phenomenon between Nigeria and 15 European Union countries using quarterly data for the period 1999 to 2012. The study indicates that the Marshall Lerner hypothesis does not hold in Nigeria's trade balance with the 15 EU countries, and could not detect the J-curve phenomenon using aggregate data for the 15 EU countries during the same period. However, disaggregated bilateral trade data between Nigeria and each of the EU15 indicated the existence of J-curve in bilateral trade between Nigeria and 4 EU countries - Austria, Denmark, Germany and Italy, while the Marshall Lerner condition exists only in the case of Luxembourg.

Empirical studies above assumed that the effects of exchange rate changes on the trade balance are symmetric. However, testing the effects of appreciations and depreciations on trade balance could lead to asymmetric results, with depreciations having significant effects while appreciations may not. Consequently, Bahmani-Oskooee and Fariditavana (2016) indicate that the relationship could be non-linear and applied the non-linear ARDL approach to investigate the asymmetric effect of exchange rate changes on the trade balance. Using data for the US and its six largest trading partners, the study show that introducing a non-linear ARDL approach led them to discover more evidence of the J-curve. They further reveal that the effects of exchange rate changes on trade balance are, in most cases, asymmetric.

Following this, Iyke and Ho (2017) utilize both the linear and non-linear ARDL approach to cointegration on a quarterly data of Ghana for the period 1986 to 2016 to examine the response of the country's balance of trade to shocks in exchange rate. The study could not establish the expected short and long-run relationship between Ghana's currency depreciation and its country's balance of trade using the linear ARDL approach, thus, refuting the J-curve effect. However, they confirm the impact of the J-curve phenomenon in Ghana when the non-linear ARDL estimation was used. Their results indicate that real depreciations improves the Ghana's trade balance, while real appreciations does not have any impact on it during the period.

Given the possibility that the response of Nigeria's trade balance to changes in the Naira exchange rates could be asymmetric and thus, non-linear, adopting only a linear specification could lead to unreliable results. Consequently, this study adopts both the linear and non-linear ARDL bounds testing approach to cointegration to investigate the presence or otherwise, of the J-curve phenomenon in Nigeria.

### **3.0 OVERVIEW OF EXCHANGE RATE REGIMES AND TRADE BALANCE IN NIGERIA**

#### **3.1 Exchange Rate Regimes in Nigeria**

Exchange rate regimes are different systems for the management of exchange rate, which can be rigidly fixed, freely floating or a variant of both. Under a fixed exchange rate regime, the exchange rate of the domestic currency to a foreign currency is determined by the authorities. Revaluation occurs when the



authorities decide to strengthen the domestic currency while a deliberate decrease in the value of the domestic currency is termed devaluation. Under a floating regime, the exchange rate is market-determined. Appreciation occurs when the domestic currency gains value against the foreign currency, and depreciation arises when the reverse occurs. The type of exchange rate regime a country adopts depends, among others, on the structure of the economy, macroeconomic policy goals, the operational exchange rate policy framework, external shocks and the predications on the future external flow, including movements in external reserves (CBN 2008).

Nigeria has adopted the two major exchange rate regimes as part of exchange rate management to ensure efficient mechanism for the determination of the exchange rate and enhance the allocative efficiency of foreign exchange resources with the overall objective of maintaining internal and external balance.

### ***3.1.1 Fixed Exchange Rate Regime***

The fixed exchange rate regime in Nigeria predates the establishment of the Central Bank of Nigeria, as the country was covered by the Defense (Finance) Regulation of 1939 during the colonial period. This was replaced by the Exchange Control Ordinance of 1950 and the enactment of the Exchange Control Act of 1962 to reflect the sovereign status of the country thereafter.

The fixed regime prevailed during the 1960s up to 1973, as the gold standard monetary system was operated during that period. The Nigerian Pound maintained parity at 1:1 with the British Pound Sterling since its introduction in 1959. The parity was thereafter defined in terms of gold beginning from June 1962, and one Nigerian Pound was equivalent to 2.48828 gram of gold. The country's exchange rate maintained parity with the Pound Sterling until the devaluation of the Pound Sterling in November 1967.

The Nigerian Pound was later pegged to a basket of currencies from 1968. However, the Nigerian currency was decimalized in 1973 and the Naira came on board. The value of the Naira was then fixed at ₦1 to GB Pound 0.58 and US\$1.52, respectively. Most of the anchor currencies weakened during this period, while the Naira appreciated due to the high inflow of crude oil receipts. However, the Naira was allowed to depreciate by late 1976 to reflect the changing fortunes of the country. The currency basket method of computing the Naira exchange rate was introduced in 1978. The currencies in the basket were assigned different weights based on the relative shares of trade, with the weights of Pound Sterling and the US Dollar relatively higher than others. The Naira remained stable up to mid-1980s when heightened demand pressures for foreign exchange caused it to fluctuate. In 1985, a one currency intervention system was introduced and the US dollar was adopted as the single intervention currency. This culminated into the quoting of the Naira against the US dollar and driving the cross rates of other currencies through such quotes.

The fixed exchange rate regime induced an over valuation of the Naira and promoted an importation culture with adverse effects on the country's external reserves. It also led to high incidence of malpractices such as over invoicing of imports and under invoicing of exports. Consequently, the foreign exchange market was liberalised in 1986 to curb the mounting demand pressure on foreign exchange and conserve external reserves.

### ***3.1.2 Flexible Exchange Rate Regime***

The flexible exchange regime arose from the need to allow the market forces to determine exchange rate and thus promote its efficient allocation. Consequently, the Second-tier Foreign Exchange Market (SFEM) was introduced in 1986 as part of the foreign exchange liberalization policy in line with the Structural Adjustment Programme (SAP). The first tier of the market was for all government official

transactions which were carried out at a fixed exchange rate while the second tier was for other private sector transactions, carried out at a market-determined exchange rate. This led to the depreciation of the naira and the emergence of multiple rates. To address these issues, the two tiers were merged in 1987 to an enlarged Foreign Exchange Market (FEM). However, the merger was insufficient to curb the excessive demand pressure and the persistent depreciation of the Naira, culminating in the creation of two new segments – the interbank and the autonomous markets. The two markets were merged in January 1989 to form the Inter-bank Foreign Exchange Market (IFEM).

A dual exchange rate policy – guided deregulation – was re-introduced in 1995. This led to the introduction of the Autonomous Foreign Exchange Market (AFEM) to further deepen the foreign exchange market and later, the Inter-Bank Foreign Exchange Market (IFEM) in 1999. However, IFEM was replaced with the retail Dutch Auction System (rDAS) in 2002 mainly to narrow the premium between the official and parallel markets. Under the rDAS system, authorized dealers bid on behalf of the end-users (customers) while the CBN determine the amount of foreign exchange to be sold at the bid price. The rDAS was successful, due largely to the favourable developments at the international crude oil and the resultant accumulation of external reserves.

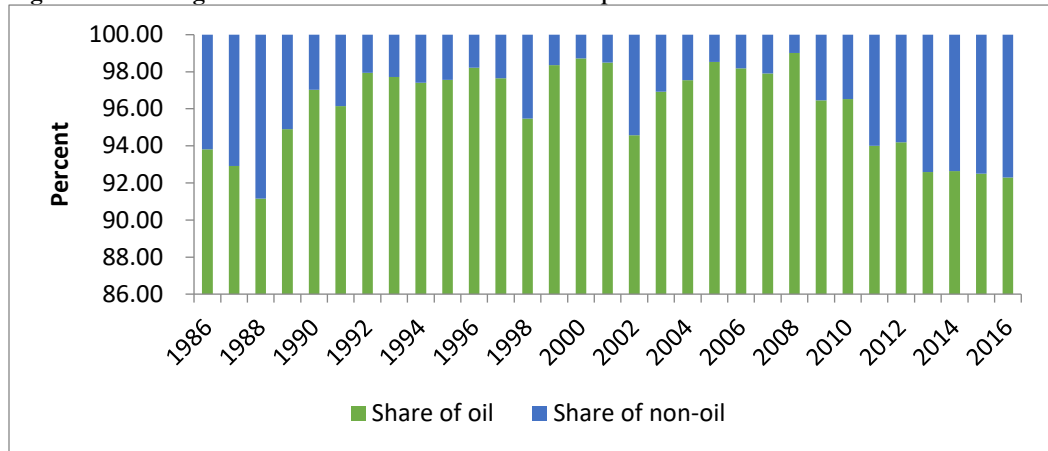
Following this success, coupled with the successful consolidation of commercial banks and enhanced fiscal discipline, the wholesale Dutch Auction System (wDAS) was adopted in 2006 to further liberalize the foreign exchange market. Licensed BDCs were recognised as authorised dealers and were allowed to access funds from the official window. The Naira remained stable all through to June 2009 after which it depreciated sharply due to the effect of the global financial crisis. This led to the reintroduction of rDAS for a brief period to December 2009. The wDAS was re-instated with some modifications, to stimulate activities in the interbank segment and stabilize the foreign exchange market.

The Bank commenced the operation of foreign exchange forward in March, 2011, as part of a strategy to hedge against risks and further deepen the market. The rDAS was re-introduced in October 2013 to once more curb unwholesome practices by authorized dealers and curtail the demand pressure and volatility in the foreign exchange market. However, it was closed on February 17, 2015, and all demands for foreign exchange were moved to the interbank segment. Furthermore, the Bank adopted a more flexible exchange rate regime on June 27, 2017 to conserve foreign exchange reserves, narrow the widening premium between the rDAS and interbank/BDCs rates as well as curb speculative activities by economic agents.

### **3.2 Overview of Nigeria's Trade**

The Nigerian economy has been characterised as mono-cultural, with agricultural products as the major export commodities in the 1960s and early 1970s. From the mid-1970s to date, the Nigerian economy has been dependent on crude oil as the main source of foreign exchange earnings. Its share in total export has remained above 80.0 per cent all through the years. For instance, during 1975-1985, crude oil export accounted for about 93.0 per cent of total export, and increased to an average of 96.0 and 97.5 per cent in 1986-1998 and 1999-2004, respectively. The improvement in gas export reduced the share of crude oil export to an average of 88.0 and 81.1 per cent between 2005 and 2010, and 2011-2015, respectively. Its share further dropped to 78.8 per cent in 2016. The share of non-oil export in total export has consistently remained below 10.0 per cent throughout the review period.

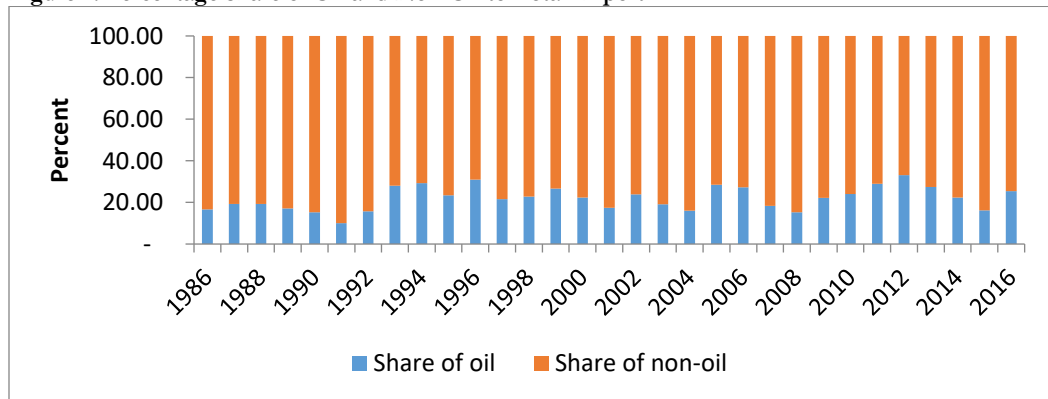
Figure 1: Percentage Share of Oil and Non-Oil to Total Export



Source: Central Bank of Nigeria

The composition of Nigeria’s import indicated that non-oil import dominated. The share of non-oil import to total import recorded an average of 85.0 per cent in four decades up to 2000. Its share, however, declined to an average of 78.9 and 74.9 per cent during 2001-2010 and 2011-2015, respectively. It further declined to 74.6 per cent in 2016. On the other hand, the share of oil import to total import during the 1960s, 1970s and 1980s was low due to the existence of functional refineries in the country. However, its share has gradually increased over the years and stood at 25.4 per cent of total import in 2016.

Figure 2: Percentage Share of Oil and Non-Oil to Total Import



Source: Central Bank of Nigeria

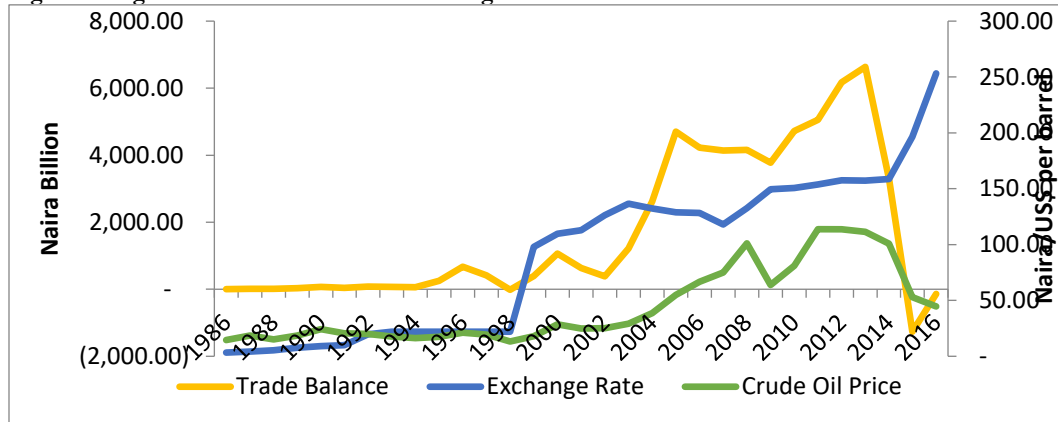
### 3.3 Trends in Nigeria's Trade Balance and Exchange Rate

Nigeria’s trade balance was in deficit during 1960s and early 1970s due mainly to import of capital goods in form of machinery in order to stimulate industrial development. However, with the commencement of crude oil export, Nigeria begin to record trade surpluses thereafter, except for the years when crude oil prices was low. For instance, from 1981 to 1983, Nigeria recorded deficit balances which averaged US\$1,628.88 million due to unfavourable developments at the international crude oil market and high import bills. From 1984, the country’s trade balances recorded surpluses up to 2015, with the exception of 1998 where a deficit of US\$2,201.41 million was recorded. This was also attributable to drop in crude

oil prices during the year, owing to low global demand. Adverse developments in the global economic environment, particularly the slump in crude oil price and low global demand led to trade deficits of US\$6,447.02 million and US\$535.05 million in 2015 and 2016, respectively.

Trends in exchange rate revealed that the Nigerian pound was fixed at N0.71/US in 1960s up to 1970 but later appreciated to N0.66/US\$1 in 1972. However, the naira exchange rate was fixed at ₦0.65/US\$1 due to the introduction of the Naira to replace the Nigerian pound in 1973. The fixed exchange rate regime continued until 1985, and in 1986 the Naira depreciated to ₦2.02/US\$1 largely due to the liberalization of the foreign exchange market. It averaged ₦11.08/US\$1 between 1987 and 1993 and depreciated to ₦22.00 in 1993. It was later fixed at ₦21.89/US\$1 by the federal government between 1993 and 1998. However, it depreciated to ₦86.32/US\$1 at the beginning of 1999.

**Figure 3: Nigeria's Trade Balance and Exchange Rate Movements**



Source: Central Bank of Nigeria

The Naira dramatically depreciated by 45 percent, declining to an average of ₦125.00/US\$1 between 2000 and 2006 and continued on this trend. It, however, appreciated to ₦117.97/US\$1 in 2007 as a result of the favourable terms of trade which led to the accumulation of external reserves. However, the adverse effect of the global financial crisis coupled with the decline in crude oil price led to excessive demand pressure at the foreign exchange market, which steered a further depreciation of the naira to ₦149.58/US\$1 in 2009 and ₦157.50/US\$1 in 2012. The naira remained stable up to the third quarter of 2014, but depreciated in last quarter of 2014 due to heightened demand pressure, which led to the introduction of new reform policies at the foreign exchange market in November 2014. The reforms included realigning the exchange rate band from  $\pm 3$  per cent to  $\pm 5$  per cent, widening the midpoint exchange rate from ₦155/US\$1 to ₦158/US\$1, and the exclusion of some invisible transactions from the rDAS window. The interbank rate was adopted for all eligible foreign exchange transactions following the closure of the official rDAS window in 2015. The naira exchange rate averaged ₦196.49/US\$1 and ₦253.19/US\$1 in 2015 and 2016, respectively.

## 4.0 ECONOMETRIC MODEL AND DATA

### 4.1 The Model

The trade balance model estimated in this study follows that of Onafowora (2003), Bahmani-Oskooee and Ratha (2004, 2007), Bahmani-Oskooee and Harvey (2009), Kyophilavong *et al* (2013) and Dash (2013). We specify Nigeria's trade balance as a function of real exchange rate, real foreign income and real domestic income as follows:

$$\ln(TB)_t = \alpha_0 + \alpha_1 \ln(REER)_t + \alpha_2 \ln(FY)_t + \alpha_3 \ln(DY)_t + e_t \quad (1)$$

Where  $\ln$  is natural logarithm,  $TB$  is a measure of Nigeria's trade balance defined as the ratio of Nigeria's total exports over its total imports. The export/import ratio or its inverse has been used in many empirical studies on trade balance – exchange rate relationship (see Bahmani-Oskooee and Brooks (1999), Bahmani-Oskooee and Kantipong (2001), Onafowora (2003), Bahmani-Oskooee and Ratha (2004) and Dash (2013), among others).  $REER$  is the real effective exchange rate, defined in a way that a decline in the rate depicts a real depreciation and an improvement in trade competitiveness.  $FY$  is the real foreign income, using the United States real GDP as a proxy,  $DY$  is the real domestic income while  $e_t$  is an error term.

A priori, we expect  $\alpha_1$  to be negative ( $\alpha_1 < 0$ ) in the long run in order to satisfy the Marshall – Lerner condition, since declining  $REER$  imply real depreciation while an increase in  $TB$  depicts increase in exports and/or decline in imports. However, we expect the trade balance to deteriorate in the short run resulting from real depreciation in line with the J-curve hypothesis. Thus  $\alpha_1$  is expected to be positive ( $\alpha_1 > 0$ ) in the short run. Meanwhile, increase in economic growth rates and national income in foreign economies tend to have a positive impact on the amount of goods and services that the foreign economy imports from the rest of the world, thereby boosting the exports of its trading partners. In view of this, we expect  $\alpha_2$  to be positive ( $\alpha_2 > 0$ ) since increase in the demand for Nigeria's exports particularly oil would swell the country's exports, thereby improving Nigeria's trade balance. Similarly, an increase in Nigeria's domestic income (real GDP growth) may increase the country's propensity to import goods and services from the rest of the world, leading to deterioration in Nigeria's trade balance. Thus,  $\alpha_3$  is expected to be negative ( $\alpha_3 < 0$ ).

A rise in real foreign income may, however, emanate from an increase in the production of substitutes for Nigeria's exports, leading a foreign country to import less from Nigeria as its national income grows, resulting in a negative  $\alpha_2$ . Similarly, an increase in domestic income could be influenced by growth in domestic production of local goods in response to domestic demand for import-substitute goods. This would lead to a fall in imports from foreign countries thereby leading to a positive  $\alpha_3$ . By implication,  $\alpha_2$  and  $\alpha_3$  could be positive or negative.

#### 4.2 Estimation Procedure

This study adopts the Autoregressive Distributed Lag (ARDL) framework (i.e. the bounds testing approach to cointegration) developed by Pesaran *et al* (2001) to assess both the long run and short run effects of real exchange rates on Nigeria's trade balance and confirm whether the J-curve hypothesis holds in Nigeria. This approach has some econometric advantages over the conventional cointegration technique proposed by Johansen and Juselius (1990) and Johansen (1991), which estimates the long run relationships within a context of a system of equations, unlike the ARDL approach, which employs only a single reduced form equation (Pesaran and Shin, 1995). First, the ARDL approach does not require pre-testing of the series to determine their order of integration since the test can be conducted regardless of whether the series are purely  $I(1)$ , purely  $I(0)$  or a mixture of both. Second, the framework is relatively more efficient in the case of small and finite samples. Third, we obtain unbiased estimates of the long run model by applying the ARDL methodology (Harris and Sollis, 2003).

We utilized the unrestricted ARDL to estimate equation 1 which would enable us to test for the existence of long run relationship among the variables. The ARDL model takes the following form:

$$\begin{aligned}
\Delta \ln(TB)_t = & \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta \ln(TB)_{t-i} + \sum_{i=0}^p \beta_{2i} \Delta \ln(REER)_{t-i} + \sum_{i=0}^p \beta_{3i} \Delta \ln(FY)_{t-i} \\
& + \sum_{i=0}^p \beta_{4i} \Delta \ln(DY)_{t-i} + \delta_1 \ln(TB)_{t-1} + \delta_2 \ln(REER)_{t-1} + \delta_3 \ln(FY)_{t-1} \\
& + \delta_4 \ln(DY)_{t-1} + e_t
\end{aligned} \tag{2}$$

Where  $\Delta$  is a first difference operator,  $t$  is time,  $\alpha_0$  is an intercept term,  $\beta_1$  to  $\beta_4$  are short run coefficients,  $\delta_1$  to  $\delta_4$  are the long run parameters of the model and  $p$ , are the optimal lag lengths. Other variables are as defined earlier. To examine the existence of long-run relationship following Pesaran *et al* (2001), we conducted the first set of tests using F- and t-statistics under the null hypothesis of no cointegration among the model's variables and also test for the joint significance of the coefficients of the lagged level variables in equation 2 as follows:

$$H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$$

$$H_1: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$$

Pesaran *et al.* (2001) provides two (2) critical values for the cointegration test. The lower critical bound assumes that all the variables are  $I(0)$  while the upper critical bound assumes that all variables are  $I(1)$ . The decision criterion is that if the computed F- and t-statistics falls below the lower bound critical values, the null hypothesis of no cointegration cannot be rejected. However, if the computed F- and t-statistics lies above the upper bound critical values; the null hypothesis of no cointegration is rejected, implying the existence of cointegration amongst the variables in the model. Note that if the computed F- and t-statistics lies between the lower and upper bounds, the result would be inconclusive. Once cointegration is established, the ARDL long run model can be estimated as follows:

$$\begin{aligned}
\ln(TB)_t = & \alpha_0 + \sum_{i=1}^p \beta_{1i} \ln(TB)_{t-i} + \sum_{i=0}^p \beta_{2i} \ln(REER)_{t-i} + \sum_{i=0}^p \beta_{3i} \ln(FY)_{t-i} + \sum_{i=0}^p \beta_{4i} \ln(DY)_{t-i} \\
& + e_t
\end{aligned} \tag{3}$$

Accordingly, the associated error correction model for equation (3) is specified as:

$$\begin{aligned}
\Delta \ln(TB)_t = & \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta \ln(TB)_{t-i} + \sum_{i=0}^p \beta_{2i} \Delta \ln(REER)_{t-i} + \sum_{i=0}^p \beta_{3i} \Delta \ln(FY)_{t-i} \\
& + \sum_{i=0}^p \beta_{4i} \Delta \ln(DY)_{t-i} + \vartheta ecm_{t-1} + e_t
\end{aligned} \tag{4}$$

Where  $\vartheta$  is the speed of adjustment parameter, which measures the speed at which equilibrium is restored following disequilibrium errors arising from shocks, while  $ecm$  is the residual error correcting variable from the long run equation 3.

The main limitation of the linear ARDL model for the Nigeria's trade balance in equation 2 is that it may fail to identify the J-curve effect if non-linearities are present in the model. While the model assume that real exchange rate and Nigeria's trade balance relationship is linear, the relationship may be non-linear such that Nigeria's trade balance may respond differently to real appreciations and depreciations. Bahmani-Oskooee and Fariditavana (2016) indicated that the effect of changes in exchange rate on the trade balance could be asymmetric such that when depreciations are separated from appreciations and

their effects on the trade balance are tested separately, depreciations in exchange rate may significantly influence the behaviour of the trade balance than appreciations. Given this, the study also adopts a non-linear ARDL framework to the Nigeria's trade balance model by decomposing  $\ln(REER)_t$  into positive (Naira appreciation) and negative (Naira depreciation) as follows:

$$\ln(REER)_t = \ln(REER)_0 + \ln(REER)_t^+ + \ln(REER)_t^- \quad (5)$$

Where  $\ln(REER)_t^+$  and  $\ln(REER)_t^-$  are the partial sums of the positive and negative changes in  $\ln(REER)_t$ , respectively. They are defined as:

$$LREERPOS = \ln(REER)_t^+ = \sum_{j=1}^t \Delta \ln(REER)_j^+ = \sum_{j=1}^t \max(\Delta \ln REER_j, 0) \quad (6)$$

$$LREERNEG = \ln(REER)_t^- = \sum_{j=1}^t \Delta \ln(REER)_j^- = \sum_{j=1}^t \min(\Delta \ln REER_j, 0) \quad (7)$$

Following Shin *et al* (2014), we replace  $\ln(REER)_t$  in equation (2) with LREERPOS and LREERNEG to arrive at a non-linear ARDL model stated below:

$$\begin{aligned} \Delta \ln(TB)_t = & \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta \ln(TB)_{t-i} + \sum_{i=0}^p \beta_{2i} \Delta LREERPOS_{t-i} + \sum_{i=0}^p \beta_{3i} \Delta LREERNEG_{t-i} \\ & + \sum_{i=0}^p \beta_{4i} \Delta \ln(FY)_{t-i} + \sum_{i=0}^p \beta_{5i} \Delta \ln(DY)_{t-i} + \delta_1 \ln(TB)_{t-1} + \delta_2 LREERPOS_{t-1} \\ & + \delta_3 LREERNEG_{t-1} + \delta_4 \ln(FY)_{t-1} + \delta_5 \ln(DY)_{t-1} \\ & + e_t \end{aligned} \quad (8)$$

Where  $\beta_1$  to  $\beta_5$  are short run coefficients,  $\delta_1$  to  $\delta_5$  are the long run coefficients of the model and  $e_t$  is the white-noise error term. Equation (8) now becomes the non-linear ARDL model and nonlinearity is introduced through the partial sum variables LREERPOS and LREERNEG. Changes in the real exchange rates would have linear effects on the trade balance if the coefficients of LREERPOS and LREERNEG have the same size, sign and are significant at the 5 percent level. Otherwise the effects are non-linear. Shin *et al* (2014) justify applying Pesaran *et al* (2001) bounds testing approach to equation (8). A non-linear ARDL error correction model would then be as follows:

$$\begin{aligned} \Delta \ln(TB)_t = & \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta \ln(TB)_{t-i} + \sum_{i=0}^p \beta_{2i} \Delta LREERPOS_{t-i} + \sum_{i=0}^p \beta_{3i} \Delta LREERNEG_{t-i} \\ & + \sum_{i=0}^p \beta_{4i} \Delta \ln(FY)_{t-i} + \sum_{i=0}^p \beta_{5i} \Delta \ln(DY)_{t-i} + \vartheta ecmt_{-1} + e_t \end{aligned} \quad (9)$$

Where coefficients are as defined earlier.

#### 4.3 Data

The study utilized quarterly time series data covering the period 1994Q1 to 2018Q2. Trade data series including merchandize exports and imports for Nigeria as well as real GDP series were obtained from the statistical database of the Central Bank of Nigeria. Real foreign income, proxied by the real GDP

of the United States (US), which is in Billions of Chained 2012 Dollars, were taken from the Federal Reserve Economic Data (FRED), which is available at the Federal Reserve Bank of St. Louis website. The real effective exchange rates (REER) were sourced from the International Financial Statistics (IFS) database.

## 5.0 EMPIRICAL RESULTS

### 5.1 Descriptive Statistics

The summary statistics of the variables used in the analysis are presented in table 1. The table showed that Nigeria's trade balance (TB) represented by its exports/imports ratio averaged 2.41 during the period, indicating that the trade balance has been in surplus for most of the period. The minimum and maximum ratios recorded during the period were 0.76 and 8.96, respectively. The minimum real effective exchange rates (REER) was 63.86 while the maximum was 275.87. Real foreign income peaked at 18,551.60 while the domestic income (DY) peaked at 18,598.07. In the same vein, dispersion in the mean of domestic income is greater than that of real foreign income. Table 1 also indicate that the asymmetry of the distribution of the variables are positively skewed except for the real foreign income that is negatively skewed. The Kurtosis also shows that the distribution of trade balance (TB) and real exchange rate (REER) are leptokurtic indicating a peak relative to the normal and show the high risk of fall in trade balance and exchange rate depreciation. On the other hand, the foreign income and domestic income has platykurtic distribution indicating that, no score is more than one standard deviation away from the mean - that is, it has no tails.

**Table 1: Summary Statistics of the Variables**

Statistic	TB	REER	FY	DY
Mean	2.41	115.07	14,546.28	11,066.72
Median	2.00	99.95	15,145.00	10,321.64
Maximum	8.96	275.87	18,511.60	18,598.07
Minimum	0.76	63.86	10,189.00	5,595.68
Std. Dev.	1.40	50.99	2,278.92	4,000.14
Skewness	1.83	1.75	-0.27	0.34
Kurtosis	7.47	5.27	2.06	1.75
Observations	98	98	98	98

### 5.2 Unit Root Tests

Even though the ARDL framework does not require pre-testing the model variables for unit root, we conducted the unit root tests in order to justify the use of the ARDL bounds testing approach to cointegration. Consequently, the study began by testing for the presence of unit root in all the variables, using both Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Empirical results from the ADF unit root tests, presented in Table 2 showed that the null hypothesis of a unit root cannot be rejected for all the variables at levels except TB, where the hypothesis was rejected at the 5 per cent level. The ADF tests on the first difference of the variables resulted in a strong rejection of the null hypothesis of a unit root for all the variables except  $\ln(DY)$ , in which the null hypothesis could only be rejected at the 10 percent level.



Table 2: Unit Root Tests

Variable	ADF Test		PP Test	
	Level	First Difference	Level	First Difference
ln(TB)	-4.12***	-10.28***	-4.20***	-11.01***
ln(REER)	-2.09	-8.69***	-2.36	-8.69***
ln(FY)	-1.85	-6.82***	-1.97	-7.06***
ln(DY)	-1.11	-3.26*	-8.16***	-18.17***
<b>Critical Values for both ADF and PP Tests</b>				
10 per cent	-3.15			
5 per cent	-3.46			
1 per cent	-4.06			

\* Significance at 10 per cent level

\*\* Significance at 5 per cent level

\*\*\* Significance at 1 per cent level

The Phillips-Perron (PP) test report ln(TB) and ln(DY) as I(0) and all other variables as I(1) series. Thus, results from the tests indicated that the series exhibited different levels of stationarity. For instance, ln(TB) was stationary at level while other variables were stationary at first difference thereby supporting the use of bound testing approach to cointegration.

### 5.3 Bounds Test for Cointegration

To investigate a long run relationship amongst the trade balance model variables, we conducted an ARDL bounds test proposed by Pesaran *et al.* (2001). The critical values for the bounds test are documented in Pesaran *et al.* (2001) and are based on assumptions regarding whether the variables in the model are I(0) or I(1). The lower bound critical values are calculated on the assumption that all the variables included in the ARDL model are integrated of order 0, while the upper bound are calculated on the assumption that the variables are integrated of order 1. The results of the ARDL bounds test for both models are presented in Tables 3 and 4.

Table 3: Linear ARDL Bounds Test for Cointegration

Variables	F-Statistics	Significance Levels	Bound critical values (Unrestricted intercept and no trend - Case III) <sup>a</sup>		t-Statistics	Significance Levels	Bound critical values (Unrestricted intercept and no trend - Case III) <sup>a</sup>	
			I(0)	I(1)			I(0)	I(1)
ln(TB)	<b>8.1801</b>	1.0%	4.29	5.61	<b>-5.3881</b>	1.0%	-3.43	-4.37
ln(REER)		2.5%	3.69	4.89		2.5%	-3.13	-4.05
ln(FY)		5.0%	3.23	4.35		5.0%	-2.86	-3.78
ln(DY)		10.0%	2.72	3.77		10.0%	-2.57	-3.46

<sup>a</sup> Bound Critical Values based on Pesaran et al (2001)

The results for the linear model showed that the model variables have a long run relationship. The calculated F-statistic value of 8.18, is higher than the upper bound critical values at 1 per cent levels. Similarly, the t-statistics of -5.39 was higher than its upper bound critical values at the 1 percent levels. This implies the presence of cointegrating relationship amongst the variables.

Table 4: Non-Linear ARDL Bounds Test for Cointegration

Variables	F-Statistics	Significance Levels	Bound critical values (Unrestricted intercept and no trend - Case III) <sup>a</sup>		t-Statistics	Significance Levels	Bound critical values (Unrestricted intercept and no trend - Case III) <sup>a</sup>	
			I(0)	I(1)			I(0)	I(1)
ln(TB)	<b>5.4468</b>	1.0%	3.74	5.06	<b>-4.8065</b>	1.0%	-3.43	-4.60
ln(REER <sup>+</sup> )		2.5%	3.25	4.49		2.5%	-3.13	-4.26
ln(REER)		5.0%	2.86	4.01		5.0%	-2.86	-3.99
ln(FY)		10.0%	2.45	3.52		10.0%	-2.57	-3.66
ln(DY)								

<sup>a</sup> Bound Critical Values based on Pesaran et al (2001)

In the case of the non-linear ARDL model, the null hypothesis of no cointegration amongst the variables included in the model was rejected at the 1 per cent significance level, as both the F- and t-statistics were higher than the upper bound critical values in both tests. This implies that the variables included in the model are also co-integrated.

We avoided overfitting the models by restricting the maximum lag lengths to 4, and utilized the Akaike Information Criterion (AIC) to choose the optimal lags. The selected ARDL representations for both the linear and non-linear models were ARDL (1 0 2 0) and ARDL (1 0 0 2 0), respectively.

#### 5.4 Regression Results

The empirical results of the long run models are presented in Table 5. Results from the linear ARDL model indicated that all the variables are statistically significant determinants of Nigeria's trade balance. The coefficient of real effective exchange rate (ln(REER)) carried the anticipated negative sign and is significant at the 1 per cent level. This indicates that real exchange rate depreciation would lead to an improvement in Nigeria's trade balance, through increase in exports and/or decline in imports, largely conforming to the Marshall – Lerner hypothesis. This result was consistent with the findings of Adeniyi *et al* (2011), Bahmani-Oskooee and Gelan (2012) and Igue and Ogunleye (2014). Bahmani-Oskooee and Gelan (2012) indicated that real depreciation improves trade balance in the long run only in Egypt, Nigeria and South Africa out of the nine countries studied. Igue and Ogunleye (2014) estimation of elasticity of a unit change in real depreciation to improvement in Nigeria's trade balance shows 1.16 per cent for the period 1985 – 2010, compared with 1.26 per cent estimated by this study, and further confirms that the Marshall – Lerner condition holds in Nigeria.

Real foreign income appeared to be a significant determinant of the trade balance in Nigeria during the period. This result showed that growth in foreign income tend to worsen the trade balance in the long run. This perhaps captures the decision of US, Nigeria's major trading partner to significantly cut oil import from Nigeria by developing its shale oil in addition to importing from cheaper sources. This development could potentially affect Nigeria's trade balance in the long run.

**Table 5: Estimated Long-run Model**

Dependent Variable is ln(TB)			
Variable	Coefficient	Standard Errors	P values
Linear ARDL Model			
C	37.80	14.04	0.009
ln(REER)	-1.26	0.33	0.000
ln(FY)	-4.82	2.15	0.027
ln(DY)	1.60	0.88	0.072
Non-Linear ARDL Model			
C	0.84	37.05	0.982
ln(REER <sup>+</sup> )	-1.59	1.04	0.130
ln(REER <sup>-</sup> )	-1.11	0.39	0.005
ln(FY)	-0.86	4.01	0.830
ln(DY)	0.97	1.04	0.351

An examination of the direction of Nigeria's crude oil exports for the period 2011 to 2015 indicated that crude oil exports to the United States declined gradually from a peak of N3,506.3 billion in 2011 to N1,425.6 billion and N204.3 billion in 2013 and 2015, respectively<sup>4</sup>. This was in spite of the fact that the US was the major importer of Nigeria's crude oil, and absorbed about half of its total exports in 2004 (Aliyu and Bawa, 2015). This result largely corroborates that of Baba and Yazici (2016) which found that an increase in the foreign real income of only three EU countries (Portugal, Spain and United Kingdom) lead to an improvement in Nigeria's trade balance whereas the increase in income in six other EU economies worsen its bilateral trade balance.

The coefficient of domestic real income was found to be positive and significant at the 10 per cent level. The result implies that a unit increase in domestic income would improve the trade balance by 1.60 per cent. This result largely supports those of Adeniyi *et al* (2011) and Igue and Ogunleye (2014), and imply that the rise in imports resulting from income growth tend to boost exports.

Empirical results from the non-linear ARDL long run model shows that the variables have similar signs with those in the linear model, but only one was statistically significant. The results indicate that both real appreciation ( $\ln(REER)_t^+$ ) and real depreciation ( $\ln(REER)_t^-$ ) were negative. However, real appreciation is not significant while real depreciation is significant at the 1 percent level. This results confirm that the impact of exchange rate changes on trade balance in Nigeria is asymmetric, with real depreciations significantly influencing Nigeria's trade balance, while real appreciations does not have any impact on the trade balance. The results confirm the findings of Bahmani-Oskooee and Fariditavana (2016) and Iyke and Ho (2017) that real appreciations and real depreciations have distinct impact on trade balance.

To confirm the J-curve hypothesis in Nigeria during the study period, the sign of the coefficient on real effective exchange rate ( $\ln(REER)$ ) should be positive in the short run. Empirical results from the short run linear model as presented in table 6 showed that the coefficient of the real effective exchange rate was also negative in the short run linear model and is significant at the 1 percent level. The non-linear model also indicate that both real appreciation and real depreciation remain negative, with real

<sup>4</sup> CBN Annual Report for 2015, table 65, page 284

depreciation significant at the 1 percent level, while real appreciation is not significant. This further reinforces the asymmetric impact of exchange rate changes on trade balance in Nigeria during the study period. This findings indicate that the J-curve hypothesis does not hold during the study period.

However, our finding is consistent with similar empirical results on Nigeria including Douglason (2009) study using Nigeria's disaggregated trade data which showed that the J-curve does not exist in the Nigeria's agricultural sector, while Umoru and Eboreime (2013) also rejected the prevalence of the J-curve hypothesis in the Nigeria's oil sector. Similarly, Umoru and Oseme (2013) and Igue and Ogunleye (2014) short run results both obtained by applying a vector error correction methodology (VECM) did not found any evidence of J-curve phenomenon in Nigeria. In a similar study of Africa, Bahmani-Oskooee and Gelan (2012) did not observed the existence of J-curve phenomenon in nine African countries including Nigeria.

**Table 6: Estimated Short-run Model**

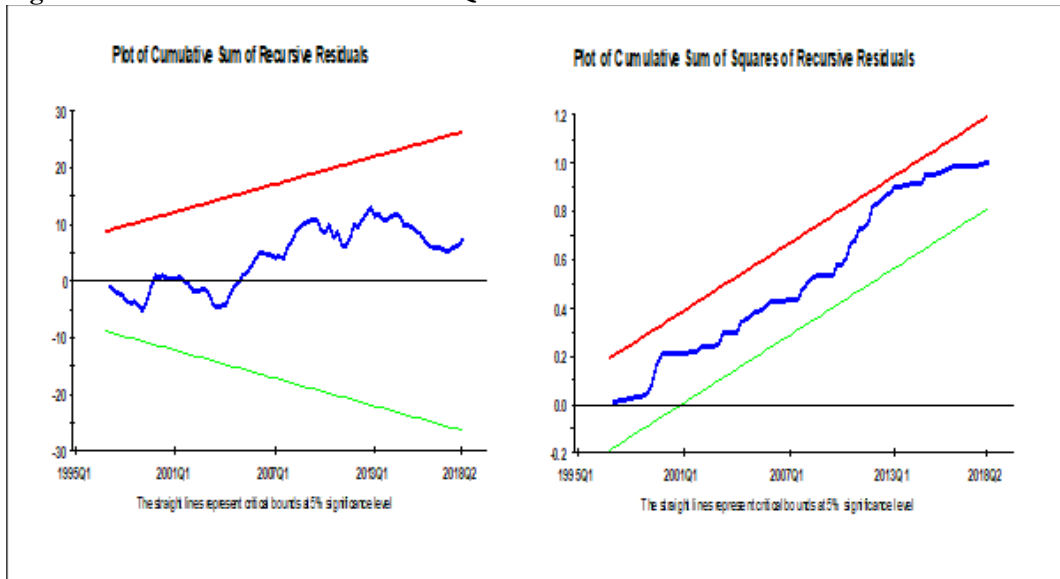
Dependent Variable is $\Delta TB$			
Variable	Coefficient	Standard Errors	P values
Linear ARDL Model			
$\Delta \ln(\text{REER})$	-0.50	0.12	0.000
$\Delta \ln(\text{FY})$	5.78	6.25	0.357
$\Delta \ln(\text{FY}(-1))$	10.99	6.20	0.080
$\Delta \ln(\text{DY})$	0.63	0.32	0.051
$\text{ecm}(-1)$	-0.39	0.07	0.000
F-Statistics	LM	RESET	ARCH
22.010 (0.000)	0.622 (0.648)	0.339 (0.562)	0.280 (0.598)
Non-Linear ARDL Model			
$\Delta \ln(\text{REER}^+)$	-0.54	0.38	0.152
$\Delta \ln(\text{REER}^-)$	-0.38	0.12	0.002
$\Delta \ln(\text{FY})$	9.85	5.90	0.099
$\Delta \ln(\text{FY}(-1))$	7.90	5.77	0.174
$\Delta \ln(\text{DY})$	0.33	0.35	0.353
$\text{ecm}(-1)$	-0.34	0.07	0.000
F-Statistics	LM	RESET	ARCH
23.335 (0.000)	0.515 (0.725)	0.096 (0.758)	0.387 (0.535)

Meanwhile, the contemporaneous coefficient of real foreign income have the appropriate sign but does not indicate any statistically significant impact on Nigeria's trade balance in the short run linear model. However, the first lag of real foreign income was positive and significant at 10 percent, indicating that, contrary to the long run results, growth in foreign real income improves Nigeria's trade balance in the short run. The non-linear model showed that the contemporaneous coefficient of real foreign GDP was significant at 10 percent while its first lag was not significant. The domestic real income coefficient was found to be positive and significant at the 10 per cent level in the short run linear model, but was insignificant in the short run non-linear model. On the other hand, the error correction term (ECM) coefficients were negative and statistically significant at the 1 per cent level in both models, further providing additional evidence on the existence of a long run relationship among the model variables. The coefficients indicated that about 39 per cent of the deviations from an equilibrium path arising

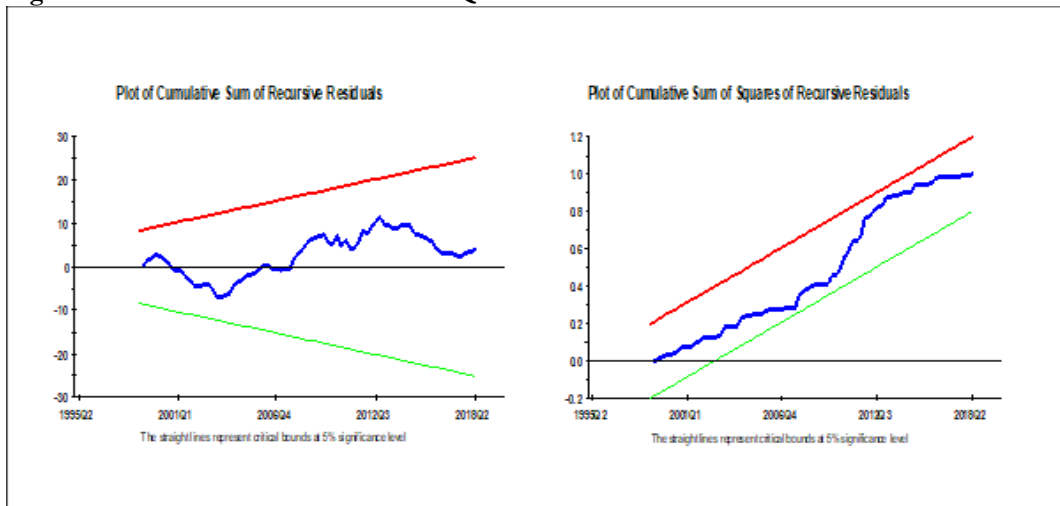
from the model would be restored within a period of one quarter in the linear model, and about 34 percent would be restored within a quarter in the non-linear model.

We conducted some robustness tests in the model firstly with a residual serial correlation LM tests to check for serial correlation, and the results indicated that the residuals are free of autocorrelation in both models. The ARCH tests also showed that the residuals for the two models were consistent with postulation of homoscedasticity in the residuals. The Ramsey's RESET statistic was carried out in order to check for misspecification error and the result indicated that the two models were correctly specified. We also test for the stability of the two models by applying the CUSUM and CUSUMSQ tests. The result from the graph in Figure 4 and 5 confirmed the stability of both the linear and non-linear ARDL models, as recursive residuals were found to be located within the two critical bounds.

**Figure 4: Plot of CUSUM and CUSUMSQ for the Linear ARDL Model**



**Figure 5: Plot of CUSUM and CUSUMSQ for the Non-Linear Model**



## 6.0 SUMMARY AND CONCLUSION

Empirical studies have distinguished the short-run effects of devaluation or depreciation on a country's trade balance from its long-run effects. It is argued that a country's trade balance deteriorate in the short-run in response to currency devaluation/depreciation, and would only improve in the long-run, culminating in the J-curve phenomenon. Reasons adduced for this short-run response include the occurrence of substantial lags prior to the expansion in exports and the contraction in imports that are normally heralded by currency depreciation or devaluation and the occurrence of a currency contract period. This paper employed both the linear and non-linear ARDL bounds testing approach to cointegration and utilized quarterly data spanning the period 1994 to 2018 to test whether the J-curve phenomenon holds in Nigeria.

Results from the analysis indicated that the model variables exhibited different levels of stationarity. The bound tests showed that the variables were cointegrated in both the linear and non-linear models, as the computed F- and t-statistics were found to be higher than the upper bound critical values at the 1 percent level. Empirical results from the long-run linear model revealed that real depreciation would lead to an improvement in Nigeria's trade balance, through increase in exports and/or decline in imports, largely in conformity with Marshall – Lerner postulations. The long run non-linear ARDL model result showed that the impact of real exchange rate changes on trade balance in Nigeria is asymmetric, as real depreciation played a significant role in influencing Nigeria's trade balance, while real appreciation does not have an impact. It also indicated that growth in foreign income tend to worsen the trade balance, while growth in domestic income play an important role in improving Nigeria's trade balance in the long-run. The short-run analysis revealed that the J-curve phenomenon does not hold in Nigeria, as the coefficient of the exchange rate remained negative and significant. These results corroborate earlier studies on testing the J-curve hypothesis in Nigeria that a depreciation of the Naira leads to improvements in the trade balance in both the short-run and long-run.

Even though depreciation of Nigeria's domestic currency in periods of trade imbalances could improve the trade balance in Nigeria, it could have undesirable consequences on the domestic price level. As discussed earlier, substantial part of Nigeria's foreign earnings come from oil exports while the country imports considerable amount of consumables including refined petroleum. Consequently, domestic prices would rise with currency depreciation and import of foreign goods thereby instigating inflation. Besides, it would also affect the country's trade balance. In the face of this threat, Nigeria's policymakers need to sustain the implementation of existing policies that encourage domestic production particularly in the food sector. Currently, the monetary authorities have imposed restrictions on accessing foreign exchange at the official window to 43 foreign items because it is understood that the country have strong capacity to produce these items.

To complement these efforts, the fiscal authority need to channel their spending on improving infrastructure that would facilitates domestic production. Prominent here is the power infrastructure in terms of electricity which can stimulate activities in the small and medium enterprise sector and heavy duty industries. Government may need to also take aggressive steps to move the economy away from the monolithic oil and open up other non-oil sectors such as agriculture, mining, and sold minerals development. The policies prescribed above would no doubt preserve the foreign income derived from oil export, improve the value of the naira (the local currency) and boost domestic production and revenue. These would consequently reduce the country's overdependence on volatile oil revenue and ensure a favourable trade balance.

## REFERENCES

- Adeniyi, O., Omisakin, O. and Oyinlola, A. (2011). Exchange Rate and Trade Balance in the West African Monetary Zone: Is There a J-Curve? *The International Journal of Applied Economics and Finance* 5(3), pp. 167 – 176.
- Alexander, S. S. (1952). Effects of a Devaluation on a Trade Balance, *IMF Staff Papers*, Vol. 2, No. 2, April 1952, pp. 263 – 278.
- Alexander, S. S. (1959). Effects of a Devaluation: A Simplified Synthesis of Elasticities and Absorption Approaches, *American Economic Review*, Vol. 49, No. 1 (Mar., 1959), pp. 22-42.
- Ali. D. Abbas., Johari. F., and Haji Alias. M. (2014). The Effect of Exchange Rate Movements on Trade Balance: A Chronological Theoretical Review Economics Research International Forthcoming.
- Aliyu, S. U. R. and Bawa, S. (2015). Gravity Model by Panel Data Approach: Empirical Evidence from Nigeria, *International Journal of Trade and Global Markets*, Vol. 8, No. 1, pp. 42 – 57.
- Aziz, Nusrate (2012). Does a Real Devaluation Improve the Balance of Trade? Empirics from Bangladesh Economy, *The Journal of Developing Areas*, Vol. 46, No. 2, pp. 19 – 41.
- Baba, A. K. and Yazici, Mehmet (2016). The J-Curve Hypothesis: An Investigation of Bilateral Trade between Nigeria and European Union, *Journal of International and Global Economic Studies*, Vol. 9, No. 1, pp. 46 – 74.
- Baek, Jungho, Koo, Won W. and Mulik, Kranti (2009). Exchange Rate Dynamics and the Bilateral Trade Balance: The Case of U.S. Agriculture, *Agricultural and Resource Economics Review*, Vol. 38, No. 2, pp. 213 – 228.
- Bahmani-Oskooee, M. and Hegerty, S. W. (2010). The J-and S-curves: A Survey of the recent Literature, *Journal of Economic Studies* 37, pp. 580 – 596.
- Bahmani-Oskooee, M. (1985). Devaluation and the J-Curve: Some Evidence from LDCs, *The Review of Economics and Statistics*, Vol. 67, No. 3, pp. 500 – 504.
- Bahmani-Oskooee, M. (2008). J-Curve, *International Encyclopaedia of the Social Sciences*, Macmillan, 2008.
- Bahmani-Oskooee, M. and Alse, J. (1994). Short-Run versus Long-Run Effects of Devaluation: Error-Correction Modelling and Cointegration, *Eastern Economic Journal*, Vol. 20, No. 4, pp. 453 – 464.
- Bahmani-Oskooee, M. and Brookes, T. J. (1999). Bilateral J-Curve between U.S. and Her Trading Partners, *Weltwirtschaftliches Archiv*, Bd. 135, H. 1, pp. 156 – 165.
- Bahmani-Oskooee, M. and Fariditavana, H. (2016). Nonlinear ARDL Approach and the J-Curve Phenomenon, *Open Economies Review*, Vol. 27, Issue 1, pp. 51 – 70.
- Bahmani-Oskooee, M. and Gelan, Abera (2012). Is There a J-Curve Effect in Africa, *International Review of Applied Economics*, Vol. 26, No. 1, pp. 73 – 81.

- Bahmani-Oskooee, M. and Goswami, G. G. (2003). A Disaggregated Approach to Test the J-Curve Phenomenon: Japan versus Her Major Trading Partners, *Journal of Economics and Finance*, Vol. 27, No. 1, pp. 102 – 113.
- Bahmani-Oskooee, M. and Harvey, H. (2009). The J-curve: Indonesia vs. Her Major Trading Partners, *Journal of Economic Integration*, Vol. 24, No. 4, pp. 765 – 777.
- Bahmani-Oskooee, M. and Kantipong, T. (2001). Bilateral J-Curve between Thailand and Her Trading Partners, *Journal of Economic Development*, Vol. 26, No. 2, pp. 107 – 117.
- Bahmani-Oskooee, M. and Ratha, A. (2004). Dynamics of the US Trade with Developing Countries, *The Journal of Developing Areas*, Vol. 37, No. 2 (Spring, 2004), pp. 1 – 11.
- Bahmani-Oskooee, M. and Ratha, A. (2007). The Bilateral J-Curve: Sweden versus Her 17 Major Trading Partners, *International Journal of Applied Economics*, Vol. 4, No. 1, pp. 1 – 13.
- Bickerdike, C. F. (1920), "The instability of foreign exchanges," *The Economics Journal*, March.
- Central Bank of Nigeria (2008). The Management of Foreign Exchange Market in Nigeria, CBN Briefs Series No. 2008 – 2009/08.
- Chaulagai, M. K. (2015). Testing the J-Curve Hypothesis: A Case of Nepal, *NRB Economic Review*, Vol. 27, Issue 1, pp. 17 – 36.
- Dash, A. K. (2013). Bilateral J-Curve between India and Her Trading Partners: A Quantitative Perspective, *Economic Analysis & Policy*, Vol. 43, No. 3, pp. 315 – 338.
- Dash, A. K. and Narasimhan, V. (2011). Dynamics of the Trade Balance: The Indian J-Curve, *International Journal of Economics*, Vol. 5, No. 1, pp. 61 – 76.
- Douglason, G. O. (2009). Is There a J-Curve in Nigerian Agricultural Sector? *Agricultura Tropica et Subtropica*, Vol. 42, No. 1, pp. 10 – 14.
- Duasa, J. (2007). 'Determinants of Malaysian Trade Balance: An ARDL Bound Testing Approach', *Global Economic Review* 36(1), pp. 89 – 102.
- Gupta-Kapoor, A. and Ramakrishnan, U. (1999). Is There A J-Curve? A New Estimation for Japan, *International Economic Journal*, Vol. 13, No. 4, pp. 71 – 79.
- Hacker, R.S. and A. Hatemi (2004). 'The Effect of Exchange Rate Changes on Trade Balances in the Short and Long Run', *Economics of transition* 12(4), pp. 777 – 799.
- Harris, R. and Sollis, R. (2003). *Applied Time Series Modelling and Forecasting*, Wiley, West Sussex.
- Igue, N. N. and Ogunleye, T. S. (2014). Impact of Real Exchange Rate on Trade Balance in Nigeria, *African Development Review*, Vol. 26, No. 2, pp. 347 – 358.
- Isard, P. (1995). *Exchange Rate Economics*. New York, USA: Cambridge University Press.
- Iyke, B. N. and Ho, Sin-Yu (2017). The Real Exchange Rate, the Ghanaian Trade Balance, and the J-curve, MPRA Paper No. 78211.



- Jha, R. (2003). *Macroeconomics for Developing Countries*. (2nd edition) New York, USA: Routledge.
- Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models, *Econometrica*, Vol. 59, pp. 1551–1580.
- Johansen, S. and Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration – with Applications to the Demand for Money, *Oxford Bulletin of Economics and Statistics*, Vol. 52, pp. 169–210.
- Johnson, H.G. (1972). 'The Monetary Approach to Balance-of-Payments Theory'. *Journal of financial and quantitative analysis* 7(02), pp. 1555 - 1572.
- Junz, H. B. and R. R. Rhomberg (1973). Price Competitiveness in Export Trade among Industrial Countries, *American Economic Review* 63, pp. 412 - 418.
- Khatoun, R. and Rahman, M. M. (2009). Assessing the Existence of the J-Curve Effect in Bangladesh, *The Bangladesh Development Studies*, Vol. 32, No. 2, pp. 79 – 99.
- Krueger, Anne D. (1983). *Exchange Rate Determination*, Cambridge: Cambridge University Press.
- Kyophilabong, P., Shahbaz, M. and Uddin, G. S. (2013). Does J-Curve Phenomenon Exist in the Case of Laos? An ARDL Approach, *Economic Modelling* 35, pp.833 – 839.
- Lal, A. K. and Lowinger, T. C. (2002). The J-Curve: Evidence from East Asia, *Journal of Economic Integration*, Vol. 17, No. 2, pp. 397 – 415.
- Lerner. A. (1944). *Economics of Control: Principle of Welfare Economics*, Macmillan, New York, NY, USA, 1944.
- Magee, S. P. (1973). Currency Contracts, Pass-through, and Devaluation, *Brookings Papers on Economic Activity*, 1:1973, pp. 303 – 325.
- Mahmud, S.F., A. Ullah and E.M. Yucel (2004). 'Testing Marshall-Lerner Condition: A Non-Parametric Approach', *Applied Economics Letters* 11(4), pp. 231 – 236.
- Mankiw, N.G. (2003). *Macroeconomics*. (5th Edition edition) New York: Worth Publishers.
- Metzler, L. (1948) *A Survey of Contemporary Economics*, Vol. I, Richard D. Irwin, INC, Homewood, IL.
- Ogutu. G. O. (2014). Effects of the Real Exchange Rate on the Trade Balance in Kenya: Master of Arts in Development Studies Research Paper. International Institute for Social Studies. The Netherland
- Onafowora, O. (2003). Exchange Rate and Trade Balance in East Asia: Is There a J–Curve? *Economics Bulletin*, Vol. 5, No. 18, pp. 1 – 13.
- Pesaran, M. H. and Shin, Y. (1995). An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis, Cambridge Working Papers in Economics 9514, Faculty of Economics, University of Cambridge.

- Pesaran, M. H., Shin, Y. and Smith, R. (2001). Bound Testing Approaches to the Analysis of Level Relationships, *Journal of Applied Econometrics* 16, pp. 289 – 326.
- Robinson, J. (1947) *Essays in the Theory of Employment*, Basil Blackwell, Oxford.
- Rose, A.K. (1991). 'The Role of Exchange Rates in a Popular Model of International Trade: Does the 'Marshall-Lerner' Condition Hold?' *Journal of International Economics* 30(3), pp. 301 – 316.
- Rose, Andrew K. and Yellen, Janet L. (1989). Is There a J-Curve? *Journal of Monetary Economics* 24, pp. 53 – 68.
- Schaling, Eric and Kabundi, Alain (2014). The Exchange Rate, the Trade Balance and the J-Curve Effect in South Africa, *South African Journal of Economic and Management Sciences*, Vol. 17, No. 5, pp. 601 – 608.
- Shao, Z. (2009). *Exchange Rate Changes and Trade Balance: An Empirical Study of the Case of Japan*. Singapore Management University (Singapore).
- Shin Y., Yu B., Greenwood-Nimmo M. (2014) Modelling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL Framework. In: Sickles R., Horrace W. (eds) *Festschrift in Honor of Peter Schmidt*. Springer, New York, NY.
- Sulaimon, O. B., Omotunde, O. and Haorayah, B. B. (2017). Devaluation and Trade Balance in Nigeria: A Test of Marshall-Lerner Condition, *European Journal of Business and Management*, Vol. 9, No. 4, pp. 78 – 93.
- Tunaer Vural, B. M. (2016). Effect of Real Exchange Rate on Trade Balance: Commodity Level Evidence from Turkish Bilateral Trade Data, *Procedia Economics and Finance* 38, pp. 499 – 507.
- Umoru, David and Eboime, M. I. (2013). The J-Curve Hypothesis and the Nigerian Oil Sector: The ARDL Bounds Testing Approach, *European Scientific Journal*, Vol. 9, No. 4, pp. 314 – 332.
- Umoru, David and Oseme, Adaobi S. (2013). Trade Flows and Exchange Rate Shocks in Nigeria: An Empirical Result, *Asian Economic and Financial Review*, Vol. 3, No.7, pp. 948 – 977.
- Weeks, J. (2001) 'Macroeconomic Policy for Growth, with Reference to Africa South of the Sahara', in T. McKinley (ed.) *Macroeconomic Policy, Growth and Poverty Reduction*, pp. 46-79. New York: Palgrave.
- Ziramba, E. and Chifamba, R. T. (2014). The J- Curve Dynamics of South African Trade: Evidence from the ARDL Approach, *European Scientific Journal*, Vol. 10, No. 19, pp. 346 – 358.