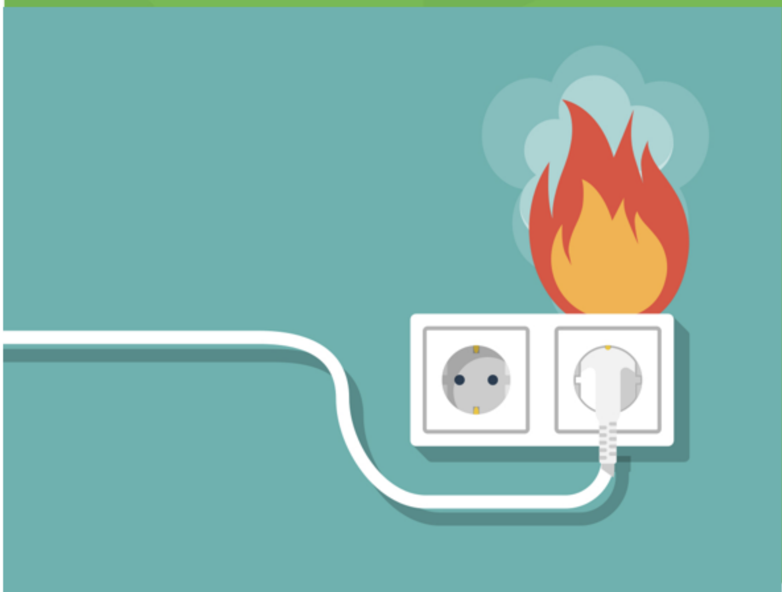
DBN Development Bank of Nigeria
...Financing Sustainable Growth

DBN JOURNAL OF ECONOMICS & SUSTAINABLE GROWTH
VOLUME 4, ISSUE 2, 2021



ENERGY CONSUMPTION AND INTERNATIONAL TRADE IN NIGERIA: EVIDENCE FROM AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) AND GRANGER CAUSALITY

BY
SEBIL OLALEKAN OSHOTA
NIGERIAN INSTITUTE OF SOCIAL AND ECONOMIC RESEARCH (NISER)
IBADAN, NIGERIA
(OSHOTA4REAL@YAHOO.COM)

This study examines the link between energy consumption and international trade in Nigeria using annual data from 1980 to 2018. The results which were based on the Autoregressive Distributed Lag (ARDL) methodology show that energy consumption significantly improves trade both in terms of total trade, imports and exports in Nigeria.

Specifically, a 1% increase in energy consumption *(ENE)* leads to 5.16 % in total trade. Similarly, a 1% increase in energy consumption increases imports and exports by 1.02% and 10.35% respectively. Domestic income and exchange rate were found to be important determinants of total trade and imports, though with different implications. While increase in domestic income by 1% raises total trade by 1.61% and imports by 0.60%.

The Granger causality showed a bi-directional causality between energy consumption and total trade on the one hand and between energy consumption and imports on the other hand. Since trade can affect economic activity by enhancing trade volume and, consequently, the energy consumption level, policymakers should develop appropriate policies to profit from trade without jeopardizing energy consumption.

Again, the increase in trade volume due to the increasing use of energy is likely to have an environmental consequence. Therefore, policymakers must evolve energy conservation control measures to reduce overall energy consumption without imposing dire implications on trade. This is essential because expanding domestic output and international trade can reshape energy demand due to scale effect.

Keywords: *Energy Consumption, Trade, ARDL, Exchange rate, Granger Causality.*

1. Introduction

Studying the relationship between international trade and energy consumption has become an important subject of concerns to economists on account of several reasons. One, if energy consumption is discovered to have Granger cause trade, then any energy conservation policies that lead to reductions in energy consumption, will automatically reduce exports or imports and diminish the benefits of trade. Again, reduction in energy consumption as a result of conservative energy policies will offset trade liberalization policies designed to promote economic growth. This puts energy conservation policies at cross purposes with trade liberalization policies (Bargi-Oskooee and Bilankohi, 2016). If unidirectional Granger causality is found to run from exports or imports to energy, then energy conservation policies will not affect trade liberalization policies designed to increase economic growth. So the discussion on the trade-energy relationship is essential just as energy consumption increases with an increase in goods production, technological developments and also with population growth. Without the effective use of those goods, production cannot be possible (Shahbaz et al. 2014). An increase in domestic production can also reshape energy demand because of expansion of domestic output commonly refers to as scale effect. Such a scale effect is caused by trade openness (Shahbaz et al. 2014).

Over the past four decades, Nigeria has witnessed rapid growth in income and energy consumption/production as well as trade (Adewuyi and Adeniyi, 2015). However, the dynamic effects of trade and energy on economic development have led to some challenges in policymaking and debates. The challenges in policymaking and debates arose from the need to expand trade and the quest for energy conservation due to the nonrenewable nature of some energy sources. The forms of energy consumed in Nigeria have increased in every aspect such as in terms of intensity and diversity coupled with innovations in technological improvement and socio-economic changes. This informs the need for research to unravel the link between the two important subjects.

Despite the huge literature on the effect of energy consumption the economy of a nation particularly, on the output (GDP), very little has been explored on the connections between trade and energy. Narayan and Smith (2009) first pointed to this fact and subsequently emphasized by Sadorsky (2011, 2012). Hence, this study is justified on the following ground. First, in terms of the theoretical framework, this research is based on an energy demand model rather than an ad hoc specification used in most studies. Ad hoc models are simple to formulate and estimate, but the results can be harder to interpret because the empirical analysis is not based on economic theory. Second, three separate models are estimated, one for total trade, one for exports and one for imports. This facilitates a more detailed analysis of how energy demand affects trade flows in Nigeria. Consequently, this study presents a more complete view of the relationship between trade and energy in Nigeria. Besides, no such study has been carried out in Nigeria.

Given the aforementioned, the relevant research questions to examine are: what effect does energy consumption have on the overall trade, imports and exports in Nigeria? What is the direction of causality between trade and energy consumption in Nigeria? Hence the broad objective of this study is to investigate the link between energy consumption and trade in Nigeria. In specific term, the objectives are to assess the impact of energy consumption on total trade, imports and exports as well as to determine the direction of causality between them.

Following the introduction section, section two presents the literature review. The theoretical foundation for this study and the methodology adopted are explained in section three. Section four discusses the empirical results and findings of the study, while Section four provides the conclusion of the study.

2. Literature Review

The traditional trade theory, such as the resource endowment theory of Heckscher–Ohlin, has been used to explain the role of energy in international trade (Adewuyi, 2015; Tarek, Yousef and Haider, 2019). According to the theory, countries specialize in the production and international trade as per their abundant resources. As such, nations may specialize in capital-abundant or labour-abundant production process to enhance international trade. In both cases, countries may increase the demand for energy to fuel the production process. With increasing international trade, the increasing production raises energy consumption than that of autarky situation if energy efficiency method could not be applied. In contrast, energy demand may reduce if energy-efficient technologies are employed with increasing international trade. Therefore, increasing or decreasing energy consumption with increasing trade is an empirical question for any economy.

Empirically, several studies have investigated the impact of trade / trade openness on energy consumption. However, some studies have shown that trade can also been influenced by energy consumption. Despite this connection, the literature on trade and energy link are still scarce. For a quick glance, the few studies that have directly or indirectly (through output, or GDP) examine the relationship between energy consumption and trade in recent time include (Ben-Aïssa, Jebli and Youssef, 2014; Shahbaz, Nasreen, Ling and Sbia, 2014; Shakeel, Iqbal and Majeed, 2014; Kyophilavong, Shahbaz, Anwar and Masood, 2015; Adewuyi and Adeniyi, 2015; Wu and Chen (2017); 2018; Koengkan, 2018; Topcu and Payne; Amri, 2019). The empirical findings of these studies are hereby reviewed accordingly.

Amri (2019) adopted the General Method of Moment (GMM) to investigate the effect of renewable and non-renewable categories of energy consumption on trade in four different economies of the world: developed, developing, industrialised and non-industrialised countries. The result shows that trade and energy consumption (renewable or non-renewable) have a reinforcing linear relationship that seems to be mutual. Moreover, the validity of non-linear relationships is accepted only in the case of the impact of non-renewable on trade. This latter follows an inverted U-shape form in the case of developed and industrialized countries while a U-Shape one in the case of developing and non-industrialized countries. There is positive contribution of GDP, capital, and labor on trade and energy consumption. Also, CO_2 emissions and natural resource have positive impacts on trade and nonrenewable energy while negative effect on renewable energy.

In another development, Koengkan (2018) analysed the positive impact of trade openness on consumption of energy evidence from Andean community countries. The results demonstrate that the economic growth and trade openness have a positive effect on energy consumption, while the financial openness exerts a negative effect. Topcu and Payne (2018) further examined the trade-energy consumption nexus for OECD countries for the period 1990–2015 within a nonlinear panel framework. The study shows that with respect to non-linear relationship, the trade-energy consumption exhibits an inverted U-shaped pattern, but the impacts are consistent across different measures of trade. Wu and Chen (2017) investigated the global energy use of different economic entities and how they relate to production, consumption, and international trade. The outcome of the findings shows that 15% of the energy use embodied in trade turns out to be induced by final consumption, and 85% is attributed to intermediate production.

Kyophilavong, Shahbaz, Anwar and Masood (2015) investigated the interrelationship between energy consumption and trade openness within the context of the energy-growth nexus in Thailand between 1971 and 2012. The study found Trade openness and energy consumption to be interdependent. A bidirectional relationship exists between the two implying that trade openness Granger causes energy consumption and energy consumption in return, Granger-causes trade openness. Adewuyi and Adeniyi (2015) empirically analysed trade and consumption of energy varieties for selected West Africa economies such as Benin republic, Coted'ivorie, Ghana, Nigeria, Senegal, and Togo between 1971 and 2010. The result shows that there is insignificant linkage between consumption of energy varieties and export of Benin. However, there is a one-way positive linkage running from energy varieties to import of the country. While for Coted'Ivoire, energy varieties have insignificant relationship with export and import. However, while inverse relationship runs from export to both electricity and road transport energy consumption positive (direct) association runs from import to total energy and transport energy consumption.

Within the panel error correction mechanism and Granger Causality technique, Ben- Aïssa, Jebli and Youssef (2014) examined the causal relationship between output, renewable energy consumption and trade in Africa and found that there is no evidence of causality between output and renewable energy consumption and between trade (exports or imports) and renewable energy consumption in the short run. Also, in the long-run, there is no causality running from output or trade to renewable energy. In the long-run, our estimations show that renewable energy consumption and trade have a statistically significant and positive impact on output. Adopting Panel Cointegration Method, homogenous causality and heterogeneous causality tests Approach, Shahbaz, Nasreen, Ling and Sbia (2014) investigated the causality between trade openness and energy consumption in 91 high- middle- and low-income countries for the period 1980 to 2010. They found that co-integration between trade openness and energy consumption. The relationship between trade openness and energy consumption is inverted U-shaped in high income countries but U-shaped in middle- and low-income countries. The homogenous and non-homogenous causality analysis reveals that bidirectional causality exist between trade openness and energy consumption. Finally, in a dynamic panel cointegration analysis of the relationship between energy consumption, trade and GDP of seven South Asian Countries between 1980 and 2009, Shakeel, Iqbal and Majeed (2014) show that a feedback relationship between energy consumption and GDP, between trade and GDP, between capital and GDP, and between energy consumption and exports. Also, in the long run, the feedback relationship between energy consumption and GDP is confirmed but for other variables, it is unidirectional such that causality runs from exports to energy consumption and exports to GDP.

From the above review, it is obvious clear that few studies exist in the case of African countries where trade and energy are equally important for economic growth and development. Besides, the findings are mixed and inconclusive, while none of the studies reviewed focuses on Nigeria.

3. Theoretical Framework and Methodology

3.1 Theoretical framework

The theoretical linkage between trade and energy consumption is analysed using the trade and energy demand theories. According to the classical and neo-classical trade theories (such as labour productivity theory of David Ricardo and resource endowment theory of Heckscher–Ohlin), export supply (EXP^s) is a function of domestic productive capacity or resource endowment (proxy by domestic GDP^d), and relative price (real exchange rate-RER).

$$EXP^s = (GDP^d, RER) \quad (1)$$

However, production of output is a function of inputs (K, L, I), therefore we have aggregate output equation as follows:

$$GDP = f(K, L, I(ENE)) \quad (2)$$

where K = capital; L = labour and I = intermediate inputs which in this case is the Energy (ENE).

Substituting equation (2) into (1), we have

$$EXP^s = f(K, L, ENE, RER) \quad (3)$$

Given that other inputs such as capital and labour also require energy to function, we focus on the role of energy and suppress other inputs; export supply function is as follows:

$$EXP^s = f(ENE, RER) \quad (4)$$

Similarly, export demand can be expressed as a function of foreign income (FY), and relative price-RER

$$EXP^d = f(FY, RER) \quad (5)$$

Our general export (EX) equation that combined both supply and demand factors is specified as follows:

$EXP = f(ENE, FY, RER)$ (6)

Since export is a mirror side of import when a trade balance is assumed, equation (5) can similarly be expressed for import side as:

$IMP = f(ENE, DY, RER)$ (7)

While DY represent domestic income. When the domestic income rises, it is expected that demand for domestic income rises. This also affect import of goods and services by increasing their demand.

Since the elements that affect exports and imports also affect the overall trade, then the functional relationship between total trade and energy consumption can take the following form:

$TRD = f(ENE, DY, FY, RER)$ (8)

3.2 Methodology

3.2.1 Model Specification

Based on the above theoretical explanations for the relationships between trade and energy consumption (henceforth) and other explanatory variable (domestic private credit), the following econometric models are specified for estimation.

$IMP = \beta_0 + \beta_1 ENEC + \beta_2 FY + \beta_3 RER + \beta_4 DPC + \varepsilon_i$ (9)

$EMP = \beta_0 + \beta_1 ENEC + \beta_2 DY + \beta_3 RER + \beta_4 DPC + \varepsilon_i$

(10)

$TRD = \beta_0 + \beta_1 ENEC + \beta_2 FY + \beta_3 DY + \beta_4 RER + \beta_5 DPC + \varepsilon_i$

(11)

Where *IMP* is the imports of goods and services, *EXP* is the exports of goods and services, *TRD* represents the total trade, *ENEC* is energy consumption *FY* is the foreign income, *DY* is domestic income, *RER* is real effective exchange rate, and x_i represent the explanatory variable –*DPC* (domestic private credit)

Expressing the relationship in linear form using the variables in natural log in order to minimize the scale effect of numbers, we arrive at the following estimating equation:

$$logIMP = \beta_0 + \beta_1 logENEC + \beta_2 logDY + \beta_3 logRER + \beta_4 logDPC + \varepsilon_i$$

(12)

$$logEXP = \beta_0 + \beta_{1log} ENEC + \beta_2 logFY + \beta_3 logRER + \beta_4 logDPC + \varepsilon_i$$

(13)

$$logTRD = \beta_0 + \beta_1 logENEC + \beta_2 logDY + \beta_3 FY + \beta_4 logRER + \beta_5 logDPC + \varepsilon_i \qquad (14)$$

3.3 Estimation Techniques

The estimation procedure adopted in this study is in three sequences. These include the carrying out unit root test or testing for stationary, and the Autoregrssive Distributed lag (ARDL) estimation.

3.3.1 Testing for Stationarity

This is also known as unit root test. The time series data usually exhibit a non-stationary process and if ordinary least squares (OLS) is applied directly, it gives spurious result. To stem the problem of spurious regression and to avoid the problems of heteroscedasticity and autocorrelation, it is necessary that the time series property of the set of data in the estimation of the equation is confirmed. The Augmented DickeyFuller (ADF) and Phillip-Perron (PP) unit root tests are employed in this study to test the integration level in order to determine the order of integration of the variables. The auxiliary regression is run with an intercept and is specified as:

$$\Delta Y_t = \propto_0 + \propto_1 Y_{t-1} + \sum_{j=1}^{P} \gamma_j \Delta Y_{t-j} + \varepsilon_t \qquad (1)$$

WhereY_t is the variable, whose time-series properties are being investigated, $\Delta$is the difference operator, and whereε_t is the random error term with *t* = *1…n* is assumed to be Gaussian white noise. The augmentation term is added to convert the residuals into white noise without affecting the distribution of the test statistics under the null hypothesis of a unit root. As Alba and Troya (1999) noted, the ADF test has a null of unit root against the alternative of trend stationary. The asymptotic distribution of the PP test is the same as the ADF. While the ADF takes care of possible serial correlation in the error terms by adding the lagged difference terms of the regress and, and Phillips-Perron (PP) tests statistics uses nonparametric statistical methods to take care of the serial correlation in the error terms without adding lagged difference. With this test we can determine whether the variable used are stationary or free of a unit root. But if they are not stationary, then we move to the next step and that is the differencing of the variables at hand.

3.3.2 Autoregressive Distributed Lag (ARDL)

To decide the long-run association among variables of the defined models, an Autoregressive Distributed Lag (ARDL) was applied. The model was developed by (Pesaran,1997; Pesaran et al. 2001) noting that the conventional integration techniques are not efficient to well explain the long-running relationship (Uddin et al. 2013). The ARDL method also works well for small sample sizes (Pesaran, 2001) and removes the issue of omission bias and serial correlation in residuals. Additionally, the ARDL methods give unbiased estimates for the long-run relationship and reliable t-statistics even if the problem of endogeneity prevails in the model (Harris and Sollis, 2003). This technique gives reliable results even if this study has mix stationarity trends. Some of the variables are I (0), and some are I (1), however, ARDL is invalid in the case of I (2). However, the ARDL has some limitations that need to be considered before analyzing data like error terms. They must not have autocorrelation problems with each other, the mean and variance of the model remain constant, and data should follow a normal distribution. To mitigate the limitations of ARDL, this study used the Granger causality test proposed by (Engle and Granger, 1987) to check the directional of causality between variables under investigation. However, there are certain limitations of this model like variance and this means it should not change over the period and the Granger causality test produces signals only for a linear form of the model. To lessen these limitations, this study fulfilled prerequisite conditions before the use of this model. Furthermore, a list of the diagnostic tests was applied to review the efficiency of models and this test includes the Cusum Test, Breusch-Godfrey Serial Correlation LM Test, and Heteroscedasticity Test of Breusch- Pagan-Godfrey and Jarque-Bera test.

3.4 Variable Definitions and Sources of Data

This study makes use of secondary data sourced from the World Bank World Development Indicators (WDI). The data collected covers the period of 1980 – 2018. The variable names, their descriptions and data source are provided in Table 3.1 below.

Table 3.1: Variable Definitions and Sources of Data

Variables	Variable name	Description	Source
Dependent Variable			
TRD	Total trade	Total Exports and imports of goods and services (% of GDP)	WDI
EXP	Total exports	Exports of goods and services (% of GDP)	WDI
IMP	Total imports	Imports of goods and services (% of GDP)	WDI
Independent Variables			
DPC	Domestic credit to private sector	Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations	WDI
ENEC	Energy Consumption	Energy use (kg of oil equivalent per capita)	WDI
DY	Domestic Income	GDP (constant 2010 US$)	WDI
FY	Foreign Income	World income (constant 2010 US$)	WDI
REER	Real (effective) Exchange Rate	The real effective exchange rate (REER) is the weighted average of a country's currency in relation to an index or basket of other major currencies	WDI

Source: Compiled by the author

4. Empirical Results

4.1 Preliminary analysis

4.1.1 Descriptive analysis

The characteristics of the distribution of the variables are presented in Table 4.1. In statistics, the Jarque-Bera test, a type of Lagrange multiplier test, is a test for normality. This statistic measures the difference of the skewness and the kurtosis of the series with those from the normal distribution. The null hypothesis is that the series is normally distributed against the alternative that it is not. Evidently, the Jarque-Bera statistic rejects the null hypothesis of normal distribution for the value of domestic private credit *(DPC)*, real effective exchange rate *(REER),* and domestic income *(DY)* since their probability value is less than 0.05. However, the null hypothesis of normal distribution is accepted for total trade *(TRD),* imports *(IMP)*, exports *(EXP),* energy consumption (*ENE)* and foreign income (*FY)* variables.

Table 4.1 Descriptive analysis results

	TRD	***IMP***	***EXP***	***ENE***	***DPC***	***REER***	***DY***	***FY***
Mean	32.42	13.02	19.39	721.39	9.79	152.32	2.33E+11	5.03E+13
Median	34.18	12.99	20.97	715.44	8.17	100.00	1.61E+11	4.78E+13
Maximum	53.28	22.81	36.02	798.30	22.29	531.82	4.64E+11	7.96E+13
Minimum	9.14	3.03	5.25	665.10	4.96	48.92	1.08E+11	2.78E+13
Std. Dev.	12.77	5.35	8.34	39.02	4.34	119.15	1.24E+11	1.62E+13
Skewness	-0.32	-0.01	-0.15	0.33	1.15	1.70	0.799051	0.285001
Kurtosis	2.10	2.42	2.02	1.72	3.65	5.10	2.103259	1.804346
Jarque-Bera	2.00	0.55	1.70	3.36	9.28	26.08	5.456869	2.851047
Probability	0.37	0.76	0.43	0.19	0.01	0.00	0.065321	0.240383
Sum	1264.21	507.96	756.25	28134.02	381.81	5940.58	9.09E+12	1.96E+15
Sum Sq. Dev.	6194.51	1088.22	2645.53	57862.23	714.39	539443.30	5.81E+23	9.94E+27
Observations	39	39	39	39	39	39	39	39

Source: Extracted from E-Views 9.0 Output

Kurtosis measures the flatness of the distribution of the series. The statistic for Kurtosis shows that *DPC* and *REER* are normally distributed. The value of domestic private credit and real effective exchange rate are leptokurtic, since their distributions are peaked (approximately greater than 3) relative to the normal. *TRD, IMP, EXP, ENEC, DY,* and *FY* are platykurtic, suggesting that its distribution is flat (less than 3) relative to the normal. Lastly, skewness is a measure of asymmetry of the distribution of the series around its mean. The statistic for skewness shows that trade variables *(TRD, IMP and EXP)* are highly negatively skewed while *DPC* and *REER* are highly positively skewed, implying that these distributions have long negative and long positive tails respectively. On the other hand, *ENE, DY* and *FY* show positive skewness but not on the high side.

4.1.2 Correlation Matrix

The result of correlation matrix as shown by Table 4.2 indicates that most of the variables were not highly correlated. The result indicated that energy consumption *(ENEC)* positively correlates with trade variables measured by *TRD, IMP* and *EXP* respectively. This also implies that most of the variables are well behaved for the regression analysis. The correlation matrix between real effective exchange rate and trade show negative relationship between them and also implies that exchange rate has a negative long run relationship in explaining the effect of energy consumption on trade.

Table 4.2: Correlation Matrix

	TRD	***IMP***	***EXP***	***ENE***	***DPC***	***REER***	***DY***	***FY***
TRD	1.0000							
IMP	0.6294	1.0000						
EXP	0.5904	0.8142	1.0000					
ENE	0.3505	0.4100	0.2819	1.0000				
DPC	0.2988	0.4304	0.1916	0.6998	1.0000			
REER	-0.5872	-0.6755	-0.6171	-0.3954	-0.1861	1.0000		
DY	0.4584	0.5267	0.3742	0.7080	0.7721	-0.4465	1.0000	
FY	0.4590	0.5270	0.3748	0.6075	0.7713	-0.4473	1.0000	1.0000

Source: Authors computation from e-view 10

4.1.3 VAR Lag Order Selection

After analyzing the descriptive statistics and correlation matrix of the variables in the model, one of the challenging tasks is to determine the optimal lag length using the Vector Autoregressive Model (VAR), since ARDL requires lag selection precision, just as the addition of lags to time series models have a direct impact on the estimation process. For this study, four lags, has suggested by the SC method (Table 4.3) is favoured.

Table 4.3: VAR Lag Order Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-746.046	NA	2.15E+16	51.79627	52.03201	51.8701
1	-644.6754	160.7947	1.14E+14	46.52934	47.94378	46.97232
2	-619.2317	31.58526	1.31E+14	46.49874	49.09189	47.31088
3	-578.5732	36.45248	7.29E+13	45.41884	49.19069	46.60014
4	-501.9064	42.29889*	7.08e+12*	41.85562*	46.80617*	43.40607*

Source: Author's computation from e-view 10
Notes: ** refers to significance at 5% level. LL: log likelihood, LR: sequential modified LR test statistic, FPE: Final prediction error, AIC: Akaike Information Criterion, SC: Schwarz information criterion, HQ: Hannan–Quinn information criterion.*

4.1.4 Stationarity/unit root test

In line with recent developments in time series modeling, unit root tests of the variables in the model were performed to determine their time series properties/characteristics. As a preliminary step for testing for cointegration, we employed Augmented Dickey Fuller and Phillips-Perron (PP) tests statistics to confirm the stationarity or otherwise of the variables used. The ADF test assumes that the residuals from the test equation are normal while the PP

Table 4.4: Unit Root Tests

	Augmented Dicky-Fuller (ADF)		**Philip-Perron (PP)**	
Variables	I(0)	I(1)	I(0)	I(1)
TRD	-2.131	-7.571*	-2.131	-7.571*
IMP	-2.021	-6.482*	-2.021	-6.482*
EXP	-2.431	-8.391*	-2.431	-8.391*
ENEC	-4.222*	-5.898*	-3.427*	-5.898*
DPC	-1.574	-7.114*	-1.574	-7.114*
REER	-4.035*	-4.646*	-5.035*	-4.646*
DY	3.419*	-4.132*	3.219**	-4.132*
FY	-1.196	-3.893**	-1.196	-3.893*

Source: Authors computation from e-view 10
*Note: I(0) & I(1) stands for order of integration at level & on first difference. *, and ** represents 1%, and 5% level of significance.*

test does not make any assumption about the residuals of the test equation. The results of the ADF unit root tests are provided in Table 4.4. The results show that all the variables except *ENEC, REER* and *DY* are non-stationary in level form since their ADF values are less than the critical values at 1%, 5% and 10% significant level respectively. So, the null hypothesis of no unit root was accepted for all other variables except *ENEC, REER* and *DY* but the null hypothesis of no unit root was rejected at first difference. For comparison, the study used the PP method, and its results are consistent with the ADF technique. Thus, we conclude that the variables have mixed order of integration i:e *I(0)* and *I(1)*. Once the stationarity has been observed we moved to check the long-run association among variables by using the ARDL estimation approach. In this case, five variables are *I(1)* and three variables are *I(0)*, this condition favourably allows the use of ARDL.

4.2 Impact of Energy Consumption on International Trade

4.2.1 Result of the ARDL Models

The results of the ARDL models for the variables of interest are presented in Table 4.5 to show the impact of energy consumption on trade. Table 4.5 reports the ARDL results for model 1 to 3 based on the lags results selected by the ARDL method. Results of bound testing in all the models fall outside the lower bound (LB) and upper bound (UB) and this show that there exist - a long-run association among the variables. According to the table, the total trade model 1 reveal that there is a positive relationship between energy consumption and total trade in the long run. The coefficient of ENE is positive and shows that one percentage change in energy consumption *(ENE)* will bring 5.159 percentage change in total trade in the long run. Domestic income *(DY)* has a positive relation with total trade in the long-run while real effective exchange rate is negatively related to total trade in the long run. A 1% increase will raise total trade by about 1.608 percent in the long run while total trade is reduced by about 0.380% with a 1% increase in real effective exchange rate.

The results of the ARDL import model (model 2) show that a significant positive relationship exist between energy consumption and imports as well as between domestic income and imports. A 1% increase in energy consumption leads to 1.021 percentage increase in imports of goods and services. Similarly, increase in domestic income by 1% increase will raise imports by about 0.597 percent in the long run. In contrast, real effective exchange rate exerts significant negative impact on imports in the long run. Imports reduces by about 17.757 % as a result of a 1% change in real effective exchange rate.

The outcome of the ARDL model 3 (export model) show that energy consumption has a positive and significant effect on exports in the long run. A percentage change in energy consumption leads to about 10.350% increase in exports. Exchange rate also appears to be an important determinant of exports. A 1% increase in exchange rate reduces exports by about 0.455% in the long run. Other variables such as the domestic private credit, domestic income and foreign income are also not significant in explaining exports in the long run.

In order to restrict the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics, we estimate the Error Correction Model (ECM). An Error Correction Model is designed for use with non-stationary series that are known to be cointegrated. Table 5.6 present the short-run association between the variables. It is noted that the models have a negative error correction term (ECM) and they are statistically significant. The negative and significant coefficient of the error correction term reveals that the variables adjust to correct imbalance in the trade variables whilst the variable coefficients show the short-run effects of the changes in the explanatory variables on the dependent variable. This further indicates the existence of a short-run relationship between energy consumption and trade.

Table 4.5: Estimated Long Run Coefficients of the Models

	Model 1: Total Trade model: ARDL (4, 3, 4, 4, 4)			Model 2: Imports model: ARDL (4, 4, 4, 4, 1)			Model 3: Exports model: ARDL (4, 3, 3, 4, 3)		
Variable	**Coefficients**	**t-stat**	**P-Value**	**Coefficients**	**t-stat**	**P-Value**	**Coefficients**	**t-stat**	**P-Value**
ene	5.159*	2.744	0.011	1.021*	5.491	0.000	10.350**	2.491	0.024
dpc	0.095	0.271	0.786	52.826	0.386	0.705	0.045	0.122	0.903
dy	1.608**	2.135	0.068	0.597*	4.476	0.000	-0.256	-0.341	0.739
fy	0.094	0.133	0.895	0.178	1.038	0.315	0.851	1.054	0.299
reer	-0.380*	-2.897	0.007	-17.757*	-4.322	0.001	-0.455*	-3.230	0.003
Constant	-0.288	-0.016	0.988	32.749	1.595	0.130	-1.681	-0.081	0.934
				Bounds Test (at 1%)					
	F- Stat =	LB	UB	**F- Stat =**	LB	UB	**F- Stat**	LB	UB
Criteria	**6.87**	3.29	4.27	**10.87**	3.29	4.27	**= 7.58**	3.29	4.27

Source: Authors computation from e-view 10

*Note: - LB & UB stands for lower and upper bound. SIC is Schwartz information Criteria for optimal lags. *,**, represents 1%, and 5% level of significance.*

Table 4.6: Estimated Error Correction Term (ECT)

Model Specifications	Coefficients	SE	t-stat	P-Value
Model 1: **ARDL (4, 3, 4, 4, 4)**	ECT (-1)	-0.124	-8.331	0.000*
Model 2: **ARDL (4, 4, 4, 4, 1)**	ECT (-1)	-1.019	-11.205	0.000*
Model 3: **ARDL (4, 3, 3, 4, 3)**	ECT (-1)	-0.261	-6.204	0.000*

Source: Authors computation from e-view 10

In order to restrict the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics, we estimate the Error Correction Model (ECM). An Error Correction Model is designed for use with non-stationary series that are known to be cointegrated. Table 4.6 present the short-run association between the variables. It is noted that the models have a negative error correction term (ECM) and they are statistically significant. The negative and significant coefficient of the error correction term reveals that the variables adjust to correct imbalance in the trade variables whilst the variable coefficients show the short-run effects of the changes in the explanatory variables on the dependent variable. This further indicates the existence of a short-run relationship between energy consumption and trade.

The robustness of the model estimates was further ascertained by carrying out various diagnostic tests on the residual of the ECM model. Diagnostic checks are crucial in this analysis, because if there is a problem in the residuals from the estimation of a model, it is an indication that the model is not efficient, such that parameter estimates from such model may be biased. Tables 4.7, 4.8 and 4.9 present the residual diagnostic for the ARDL models, and it is clearly shown that these models have no problem of serial correlation and heteroscedasticity. In addition to the values of the Jarque-Bera tests in all the models show that their residuals are normally distributed because the P-value of the series was insignificant.

Table 4.7 Model-1: Diagnostic Tests

Variable	**Coefficients**
Serial Correlation LM Test	2.473
Heteroscedasticity	0.668
Jarque – Bera	0.780
Adjusted R-Square	0.79

Serial Correlation: Ho: No serial correlation in residuals. Heteroscedasticity: Ho: No Heteroscedasticity. Jarque- Bera test: Ho: Residuals are normally distributed

Table 4.8: Model-2: Diagnostic Tests

Variable	Coefficients	SE
Serial Correlation LM Test	3.143	0.916
Heteroscedasticity	0.385	0.847
Jarque – Bera	0.654	0.238
Adjusted R-Square	0.81	

Serial Correlation: Ho: No serial correlation in residuals. Heteroscedasticity: Ho: No Heteroscedasticity. Jarque- Bera test: Ho: Residuals are normally distributed

Table 4.9: Model-3: Diagnostic Tests

Variable	Coefficients	SE
Serial Correlation LM Test	5.831	0.473
Heteroscedasticity	0.496	0.589
Jarque – Bera	0.532	0.947
Adjusted R-Square	0.72	

Serial Correlation: Ho: No serial correlation in residuals. Heteroscedasticity: Ho: No Heteroscedasticity. Jarque- Bera test: Ho: Residuals are normally distributed

4.2.2 Stability Tests

The structural stability test of the models is conducted by employing the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residual (CUSUMSQ). According to Pesaran and Pesaran, the stability of the estimated coefficients of the model should be empirically investigated. A graphical representation of CUSUM and CUSUMSQ statistics are shown in Figure 1a and 1b to Figure 3a and 3b. It is clear that the plots of both the CUSUM and the CUSUMSQ are within the boundaries and hence these statistics confirm the stability of the long-run coefficients of the energy consumption and trade measures.

4.2.3 Granger Causality Test

Granger causality test was applied to look into the direction of causality among the variables of the models (Table 4.10). For the Total trade equation there is evidence of Granger causality running from trade *(TRD)* to energy consumption *(ENE)* and from *ENE* to *TRD*. Similarly, for the import equation, evidence of bi-directional Granger causality is found between imports *(IMP)* and energy consumption *(ENE)* while Granger causality runs from real effective exchange rate *(REER)* to imports *(IMP)* and from domestic income *(DY)* to imports *(IMP)*. For the exports equation, there is evidence of Granger causality running from energy consumption to exports and from exports to domestic income.

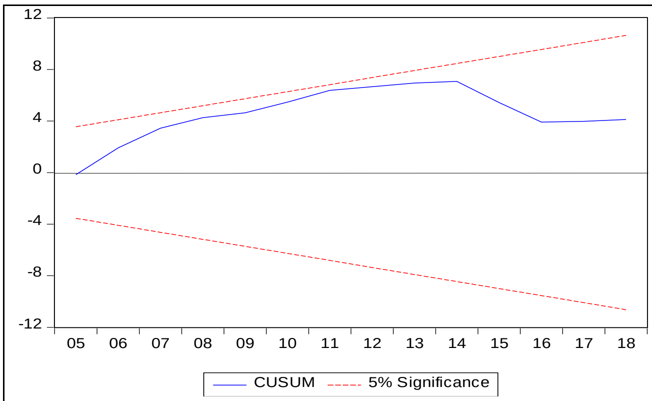


Figure 1a: Model-1: Cusum Test for Stability

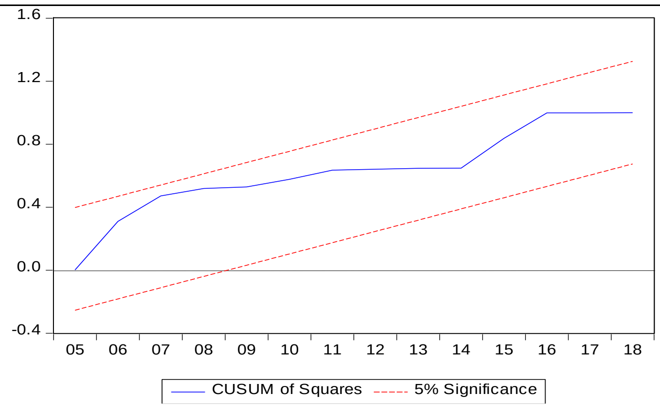


Figure 1b: Model-1: Cusum-Square Test for Stability

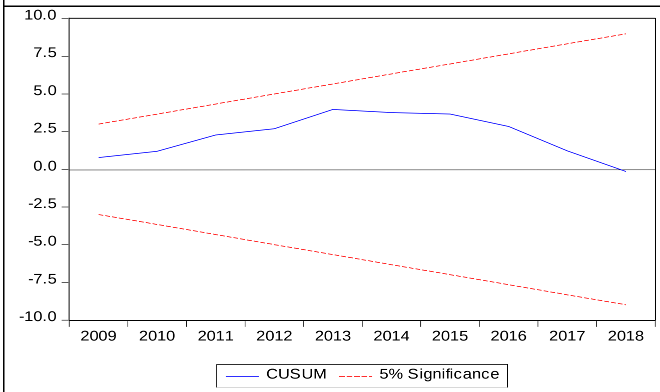


Figure 2a: Model-2: Cusum Test for Stability

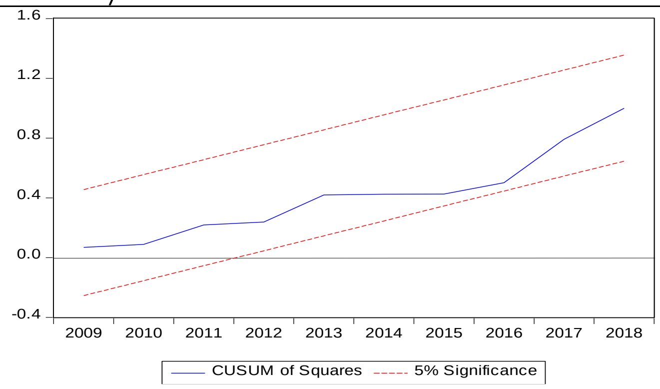


Figure 2b: Model-2: Cusum-Square Test for Stability

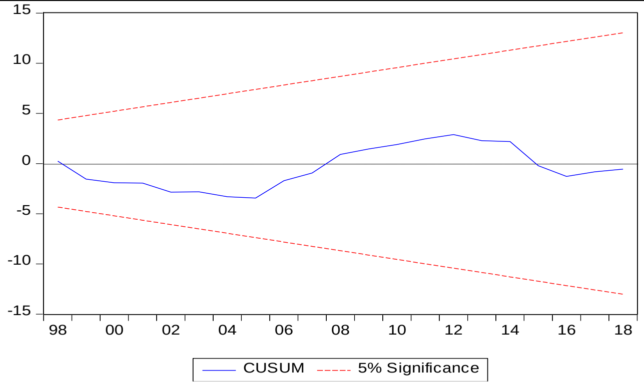


Figure 3a: Model-3: Cusum Test for Stability

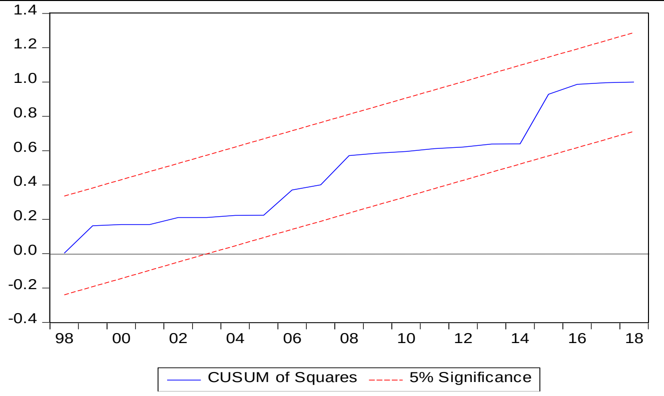


Figure 3b: Model-3: Cusum-Square Test for Stability

Source: Graphed by the Author from e-view 10

Table 4.10: Granger Causality Test

Causality Direction	F-Statistics	P-Value
ENE → TRD	4.19822	0.0240*
TRD → ENE	2.71186	0.0817***
IMP →ENE	3.52285	0.0414**
ENE →IMP	3.27215	0.0509***
DY → IMP	4.50803	0.0188**
REER →IMP	3.08838	0.0594***
ENE →EXP	3.83060	0.0323**
EXP →DY	3.86028	0.0315**

,,*** represents 1%, 5% and 10% level of significance*

5. Conclusion and Recommendation

This study analyzed the impact of energy consumption on international trade as measured by total trade, imports and exports in Nigeria for the period 1980 to 2018. For the empirical analysis, the mixed trend for the order of integrations allowed us to use the Autoregressive Distributed Lag Model technique (ARDL) for the long and short-run association. The results of the ARDL model were based on three sets of models which endorsed the existence of a long run and short-run relationship among the variables. To judge the stability of the models, the serial correlation test applied and the obtained results rule out any correlation in the models or any existing heteroscedasticity. Also, the Jarque-Bera test indicates that residuals are normally distributed. Finally, the stability of the models is also observed through the CUSUM test and CUSUM-Square test.

As regard the ARDL results, the outcome of the models show that a significant positive relationship exists between trade variables and energy consumption. A 1% increase in energy consumption *(ENE)* leads to 5.16 % in total trade. Similarly, a 1% increase in energy consumption increases imports and exports by 1.02% and 10.35% respectively. Domestic income and exchange rate are important determinants of total trade and imports. Increase in domestic income by 1% raises total trade by 1.61% and imports by 0.60%. While the total trade is reduced by 0.38% with a 1% increase in real effective exchange rate, imports is dampened by 17.78 % as a result of a 1% increase in real effective exchange rate. The results of the granger causality test revealed a bidirectional causality between total trade and energy consumption as well as between imports and energy consumption. However, a uni-directional causality running from energy consumption to exports exists. Causality also run from real effective exchange rate *(REER)* to imports *(IMP)* and from exports to domestic income.

These findings suggest that the increase in the volume of trade due to the increasing use of energy is likely to have environmental consequence. Therefore, it is imperative for policymakers to evolve energy conservation policy measures that will reduce the overall energy consumption without imposing dire consequences on its external trade. This is essential because an expansion of domestic output and international trade can reshape energy demand due to scale effect. Furthermore, since trade can affect economic activity by enhancing trade volume and, consequently, the energy consumption level, policymakers should develop appropriate energy and trade policies to profit from trade without jeopardizing energy consumption.

References

Adewuyi, A. O. and Adeniyi, O. 2015. Trade and consumption of energy varieties: Empirical analysis of selected West Africa economies, *Renewable and Sustainable Energy Reviews, Elsevier*, vol. 47(C), pages 354-366.

Alba, E. and Troya, J. M. 1999. A Survey of Parallel Distributed Genetic Algorithm," *Complexity*, 4, 31-52.

Amri, F. 2019. Renewable and non-renewable categories of energy consumption and trade: Do the development degree and the industrialization degree matter? *Energy*, 374-383.

Barghi Oskooee, M.M. and Bilankohi, M. A. 2016. The Investigation of Effect of Trade on Energy Consumption in D8. The Investigation of Effect of Trade on Energy Consumption in D8 Countries, *Energy*, Volume 7, Issue 25:12.

Ben Aïssa, M. S., Jebli, B. M. and Youssef, B.S. 2014. Output, renewable energy consumption and trade in Africa. *Energy Policy,* 66, 11–18.

Engle, R. F. and Granger, C. W. J. 1987. Co-integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55: 251-276.

Harris, R. and Sollis R. 2003. Applied time series modelling and forecasting. Wiley, New York
Halicioglu, F. 2013. A dynamic econometric study of income, energy and exports in Turkey. *Energy,* 36(5):3348–54.

Ben-Jebli, M.B., Youssef, S.B. and Oztuk, I. 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries *Ecological Indicators,* 824-831.

Koengkan, M. 2018. The positive impact of trade openness on consumption of energy: Fresh evidence from Andean community countries, *Energy,* 936-943.

Kyophilavong, P., Shahbaz , M., Anwar, S. and Masood, S. 2015. The energy-growth nexus in Thailand: Does trade openness boost up energy consumption? *Renewable and Sustainable Energy Reviews,* 46:265–274.

Narayan, P.K. and Smyth, R. 2009. Multivariate granger causality between electricity consumption, exports and GDP: Evidence from a panel of Middle Eastern countries. Energy Policy, 37, 229-236

Oskooee, B. M M and Bilankohi M. A (2016). The Investigation of Effect of Trade on Energy Consumption in D8 Countries. *Journal of Economic Modeling Research*. 7 (25):217-241

Pesaran, M. H. and B. Pesaran, 1997.*Working with Microfit 4.0*: Interactive econometric analysis. Oxford University Press, Oxford.

Pesaran, M.H., Shin, Y. and Smith, R.J. 2001. Bounds Testing Approaches to the Analysis of Level Relationships", J. *Appl. Economics.* 16, 289–326.

Sadorsky P. 2011. Trade and energy consumption in the Middle East. *Energy Economics*, vol. 33, issue 5, 739-749.

Sadorsky, P. 2012. Energy consumption, output and trade in South America. *Energy Econ*. 34,476–488.

Shahbaz, M., Nasreen, S., Hui Ling, C. and Sbia, R. 2014. Causality between trade openness and energy consumption: What causes what in high-, middle- and low-income countries, *Energy Policy,* vol. 70(C), pages 126-143.

Shakeel, M., Mazhar, I. M. and Majeed, M.T. 2014. Energy Consumption, Trade and GDP: A Case Study of South Asian Countries, *The Pakistan Development Review*, 53:4, pp. 461–476.

Tarek, T., Yousef, A. and Haider, M. 2019. Energy Consumption and Trade Openness Nexus in Egypt: Asymmetry Analysis, *Energies,* 1-10

Topcua, M., Payne, J. E. 2018. Further evidence on the trade-energy consumption nexus in OECD countries. *Energy Policy,* 160-165.

Uddin, G. S., Sjö, B., and Shahbaz, M. 2013. The causal nexus between financial development and economic growth in Kenya. *Economic Modelling,* 35, 701–707.

Wu, X.F. and Chen, G.Q. 2017. Global primary energy use associated with production, consumption and international trade, *Energy Policy,* 85-96.