Evaluating the Nexus between Energy Demand and Economic Growth Using the VECM Approach: Case Study of Nigeria, China, and the United States

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***Abstract*—**The effectiveness of energy demand policy depends on identifying the key drivers of energy demand both in the short-run and the long-run. This paper examines the influence of regional differences on the link between energy demand and other explanatory variables for Nigeria, China and USA using the Vector Error Correction Model (VECM) approach. This study employed annual time series data on energy consumption (ED), real gross domestic product (GDP) per capita (RGDP), real energy prices (P) and urbanization (N) for a thirty-six-year sample period. The utilized time-series data are sourced from World Bank's World Development Indicators (WDI, 2016) and US Energy Information Administration (EIA). Results from the study, shows that all the independent variables (income, urbanization, and price) substantially affect the long-run energy consumption in Nigeria, USA and China, whereas, income has no significant effect on short-run energy demand in USA and Nigeria. In addition, the long-run effect of urbanization is relatively stronger in China. Urbanization is a key factor in energy demand, it therefore recommended that more attention should be given to the development of rural communities to reduce the inflow of migrants into urban communities which causes the increase in energy demand and energy excesses should be penalized while energy management should be incentivized.

***Keywords*—**Economic growth, energy demand, income, real GDP, urbanization, VECM.

I. Introduction

THE relation between energy demand and economic growth has become a sensitive issue. If economic activity is taken to be a measure of welfare and continued growth is an objective, then the implications for future energy demand becomes central to the debate about energy availability, affordability, accessibility, and policies. Historical trend shows that energy demand increases at the same rate as GDP (Gross Domestic Product). The economics of energy is concerned with the way energy demand is affected by energy cost and by changes in the availability of other factors of production.

Much of the world increase in energy demand occurs among the developing non-OECD nations (outside the Organization for Economic Cooperation and Development) such as Nigeria where strong economic growth and expanding populations leads to the increase in world energy use. According to a study by EIA, Non-OECD economies such as Nigeria, energy consumption will rise by 71% from 2012 to 2040. On the contrary, OECD economies such as the US, total energy consumption will rise by just 18% within the same period [1]. This shows a correlation between energy consumption and economic growth [1]. Fig. 1 shows the world energy consumption by region.

The energy industry contributes to economic growth in various ways. Energy being an important sector of an economy, creates jobs and provides value by extracting, transmuting and distributing energy goods and services throughout an economy. In 2009 the energy industry accounted for about 4 percent of GDP in the United States. In some countries that are heavily dependent on energy exports, their share is even higher: for instance, 30% in Nigeria, 35% in Venezuela and 57% in Kuwait

The energy industry extends its reach into economies as an investor, employer and purchaser of goods and services [2].

Energy also underprops the rest of an economy as it is an input for nearly all goods and services. In many countries, the flow of energy is often not taken seriously. However, price shocks and supply interruptions can shake whole economies. For countries that face severe electricity shortages like Nigeria, continuing disruptions takes a heavy, ongoing toll on them. Economic growth accompanied with structural changes, strongly influences world energy consumption [3]. As countries develop and living standards improve, energy demand grows rapidly. For example, in nations experiencing fast-paced economic growth, the ratio of the general population demanding improved housing, which requires more energy to construct and maintain is on the increase. Increased demand for appliances, transportation equipment, and growing capacity to produce goods and services for both domestic and foreign markets, also leads to higher energy consumption. The industry directly affects the economy by using labour and capital to produce energy [2]. For over 30 years, world economic growth has been led by the non-OECD countries which seem to be complemented by strong growth in energy demand in the region. Furthermore, from 1990 to 2012, real GDP grew by 4.9%/year in non-OECD countries and 2.1%/year in OECD countries. In the future, the discrepancies in economic growth rates between OECD and non-OECD nations are expected to be contracted, as economic growth in non-OECD countries moderates, and as their industrial structures moves from

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dependence on production in energy-intensive industries to more service-oriented industries [1]. Concerns about energy security, effects of fossil fuel emissions on the environment, and sustained high world oil prices in the long term encourages the expanded use of non-fossil such as renewable energy sources, nuclear power, as well as natural gas, which is the least carbon-intensive fossil fuel.

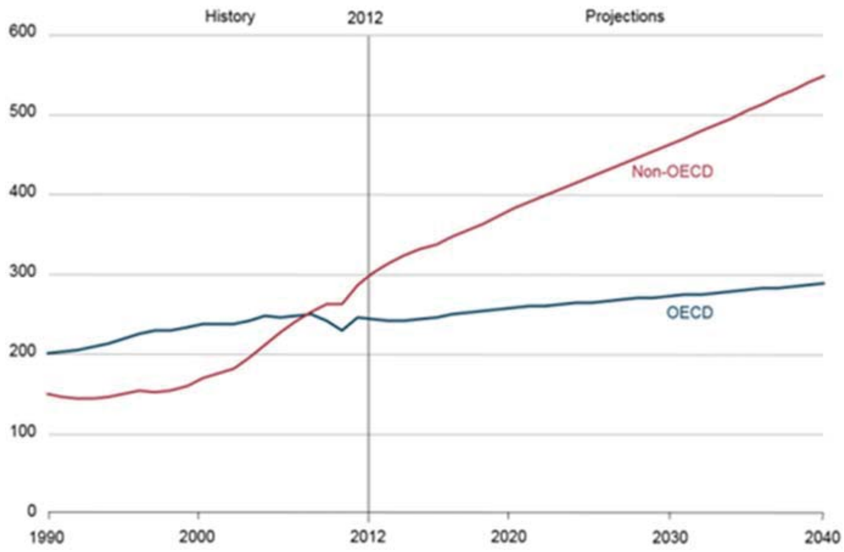

Fig. 1 World energy consumption by region, 1990 to 2040 [1]

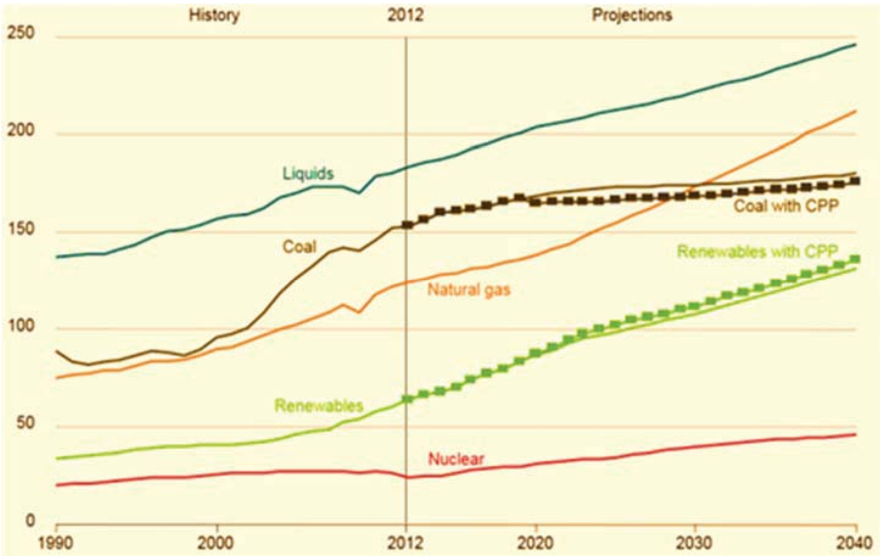

Fig. 2 World energy consumption by energy source [1]

However, from Fig. 2, we can see that fossil fuels will continue to provide most of the world's energy [1] By 2040, liquid fuels, natural gas, and coal will still account for about 78% of the world's total energy consumption. Fossil fuel, mostly petroleum and other liquid fuels will remain the largest source of energy, though their share of world's total energy consumption will decline from 33% in 2012 to 30% in 2040[1]. With future rise in global oil prices, the demand for alternative energy sources such as renewables will increase in the residential and power sector while transportation and industrial sector will increase the demand for fossil fuel.

This study tends to answer the following question; does low energy demand transcends to slow economic growth and what factors are the main drivers of energy demand.

II. Literature Review

The link between energy and development remains a key factor in development policy, which will be shaped by current trends of globalization, market and popular participation in decision-making process [4]. Economic growth and energy demand are linked but the strength of that link varies among regions and stages of economic development. For industrialized counties, history has shown the link to be relatively weak (energy demand trails economic growth) since for every percent increase in economic activity, energy demand increases only about half percent. In developing countries, demand and economic growth tend to be closely linked, with energy demand growth tending to track the rate of economic expansion. Although, growth in energy consumption in developing countries indicates improving lifestyle as a result of rising personal income [3], higher energy prices will lead to reduced economic growth. However, the possibility that past and future increase in energy prices will reduce energy demand remains questionable. Nevertheless, implications of energy scarcity and higher energy prices for future economic growth raises wider issues. The response to higher energy prices through conservation, changes in technology and in lifestyles particularly in richer industrialized countries will affect not only the future standard of living in those countries but will influence the extent and nature of economic growth in developing countries [5].

Due to the growing economy of china, that energy demand will continue to increase as it was seen between 1999 and 2014. However, this anticipated increase in energy demand has been intercepted by the presence of renewables, government policies of intentionally trying to lower energy use as well as economic transition to service and information based economy [6]. Slower economic growth reflects a decline in energy consumption due to structural economic changes [7]. However, structural changes have contributed to growth significantly by reallocating resources from low-productivity sectors to high-productivity sectors, the key improvements in overall economic efficiency are advance development of rural enterprise and increase in labor flow among sectors and across regions [8].

In Nigeria, there exists a unidirectional causality running from energy consumption to economic growth without feedback. Thus, energy conservation policies will have a negative repercussion on economic growth in Nigeria [9], since increased energy consumption is a strong determinant of economic growth [10]. However, considering the increasing energy demand that, so far, has come along with economic growth, climate change targets and continued economic growth seem to be an insurmountable contradiction. Nevertheless, a large body of literature on green growth has suggested a way of synchonizing both goals, and thus, achieving a sustainable path of economic growth [11].

According to a study done by the Energy Information Administration in the US in 2016, growth in US energy use is linked to population growth through increase in demand for housing, commercial floor space, transportation, manufacturing and service. This does not only affect the level of energy use but also the mix of fuels and consumption by sector. However, In the early September 2015, the research team of the annual World Energy China Outlook undertook a major innovation project of the Chinese Academy of Social Sciences (CASS). Their interim report indicated that with current policy scenario in china, Energy demand could reach its Plateau in 2020 and start to disassociate from Economic Growth [12]. This study therefore investigates the nexus between Energy demand and Economic growth.

III. Methodology

Energy is an essential commodity of every economic agent's demand, as result of its crucial contribution to production and consumption. Demand for energy is considered as a derived demand because it is needed in order to achieve other goods or services that satisfy agents' needs. Thus, the energy demand model is derived from the utility or production optimization.

Imagine an economy with a representative household (consumer) that has to make a choice among a bundle of commodities in order to address the issue of the utility optimization.

$$Max\ U(X)$$

$$\text{Subject to} \quad PX \leq I \tag{1}$$

where $X = [X_1, \dots \dots, X_k]$ denotes a vector of K goods and $P = [P_1, \dots \dots, P_k]$ represents the price vector of the respective K goods. Based on the equation 1, the Marshallian demand function can be written as:

$$X_k^d = X[P_1, \dots \dots, P_k, I] \ \forall \ k = 1 \dots \dots K \tag{2}$$

With the assumption of weakly separable preference, i.e. demand for commodity y does not rely on the marginal rate of substitution between any other collection of goods (k≠ y), the optimal consumption decision can be modelled in multi-stages. For the purpose of this paper, a two-stage budgeting with two groups of goods (energy good and non-energy goods) is assumed. This implies that energy demand does not depend on non-energy prices. Thus, the consumer faces the issue of optimal decision on how to allocate its spending between energy and non-energy goods:

$$Max\ U(X_E, X_N)\text{s.t}PX_E + PX_N \leq I \tag{3}$$

where X_E and X_N captures the amount of energy and non-energy goods respectively. The unconditional demand function for the two goods are as follows:

$$X_E^d = X[P_E, I, P_N\ ] \tag{4}$$

$$X_N^d = X[P_N, I, P_E\ ] \tag{5}$$

With assumption of a zero-degree homogeneity in prices and income, the paper divides the equation byP_N, the new energy demand function is specified as:

$$X_E^d = X[P_E^r,\ I^r\ ] \tag{6}$$

This indicates that energy demand depends on relative prices and real income. Although, energy demand model is often augmented with other determinants in empirical models.

Therefore, the empirical representation is as follows:

$$X_E^d = X[P_E^r,\ I^r,\ O'\ ] \qquad (7)$$

(7) can be extended to the macro level in order to estimate the aggregate energy demand model, by considering the economy as a household that makes its consumption decisions given exogenous factors such as income, prices and other non-price drivers.

This paper assumes non-energy goods as a numeraire (normalizing its price to unity), and then its empirical model is expressed as:

$$ED_t = \gamma_0 + \varphi_1 P_t \ \ + \varphi_2 RGDP_t + \varphi_3 N_t + \varepsilon_t \qquad (8)$$

where ED is energy consumption, P captures the energy prices, RGDP and N denote real income per capita and proportion of urban population in total population as a proxy for urbanization, while ε and t refer to the error term and time (annually). All these variables are specified in logs. In addition, this model utilized for each of three countries. The reviewed literature indicates that the regional differences could influence the link between energy consumption and the level of income. Therefore, the paper inculcates the urbanization variable to test for this hypothesis among China, USA and Nigeria.

A. Econometric Technique

The paper estimates the long-run energy demand model to establish the presence of co-integration using the VAR model. Then, it proceeds to estimate both the long-run and short-run elasticities with the VECM technique.

1. The Johansen Co-Integration Technique

The paper utilizes the Johansen co-integration method [13] because all variables are stationary after taking the first difference. Hence, in the event of a level relationship among the variables, the resulting long-run model is estimated as follows:

$$lnED_t = \beta_0 + \beta_1 lnP_{t-1} + \beta_2 lnRGDP_{t-1} + \beta_3 lnN_{t-1} + u_t \qquad (9)$$

The final stage is to estimate the short-run elasticities which is obtained through the error correction framework which is captured by the VECM technique. Therefore, the error correction model is written as:

$$\Delta lnED_t = \gamma_0 + \xi_{ect} ECT_{t-1} + \sum_{i=1}^{s} \lambda_{1i}\ \Delta lnED_{t-i} + \sum_{i=0}^{y} \lambda_{2i}\ \Delta lnP_{t-i} + \sum_{i=0}^{z} \lambda_{3i}\ \Delta lnRGDP_{t-i} + \sum_{i=0}^{w} \lambda_{4i}\ \Delta lnN_{t-i} + \varepsilon_t \qquad (10)$$

where ECT_{t-1} represents the error correction term while ξ_{ect} denotes the coefficient of the error term that captures the speed of adjustment of the model to its long-run equilibrium. Put differently, ξ_{ect} is the rate of correction at time t when there is a deviation from the long-run equilibrium at time t-1.

IV. Data and Results

The paper uses annual time series data on energy consumption(ED), real gross domestic product (GDP) per capita (RGDP), real energy prices (P) and urbanization (N) for the sample period, 1980-2016. Data on all the concerned variables are obtained from World Bank's World Development Indicators (WDI, 2016) and US Energy Information Administration (EIA).

TABLE I
PHILLIP PERON UNIT ROOT TEST RESULTS

Variable	PP-Statistic	Order of integration
Nigeria		
lnED	-7.53***	I(1)
lnP	-5.16***	I(1)
lnI	-4.84***	I(1)
lnU	-2.97**	I(1)
United State of America		
lnED	-6.67***	I(1)
lnP	-5.61***	I(1)
lnRGDP	-3.92***	I(1)
lnU	-2.28**	I(1)
China		
lnED	-4.39***	I(1)
lnP	-2.90*	I(1)
lnRGDP	-3.42**	I(1)
lnU	-4.48***	I(1)

*, **, *** represents 10%, 5%, 1% significance levels respectively.

A. Results of Unit-Root and Co-Integration Test

The PP unit root test indicates that all the series in three selected countries display a stationary in first difference, except real GDP per capita for the case of Nigeria. Particularly, the logs of energy consumption, price, real GDP per capita and urbanization are stationary after first difference, thus exhibiting an integration of order one I(1) (as shown in Table I).

The results of the unit root test show that the use of Johansen Co-integration approach [14] is appropriate in estimating the study's empirical model. Therefore, the paper investigates the long run relationship between energy consumption, price, real GDP per capita and degree of urbanization using the Johansen co-integration method. Table II reports the results of the Johansen test which establishes the existence of co-integration in relation to the energy demand model as indicated by trace and maximum Eigenvalue statistic. Hence, the study proceeds to estimate the demand elasticities using the VECM method.

B. Long-Run and Short-Run Energy Demand Elasticities

Having established the existence of co-integration, the study estimates both the long run and the short-run elasticities with the aid of VECM technique [15]. The VECM model is estimated in line with the Schwarz Bayesian criterion. The maximum number of lags entailed in the model is determined by the five criteria, which is 2. Results are presented in Table III.

The findings indicate in Table III all the explanatory variables (income, urbanization and price) are significant long-run determinants of energy demand in Nigeria, USA and China, but income is not a significant driver for the case of Nigeria and USA. The income elasticity of energy demand in China is positive and significant at 1 per cent, implying that a 1 percent rise in income level (real GDP per capita will increase the demand for energy by about 6.94 percent on average in the long run, holding other factors constant. Similarly, the estimate of price elasticity for USA is -1.34, indicating that a percentage increase in price will lead to a 1.34 percent fall in energy consumption in USA. In addition, the impact of urbanization on energy demand is significant in three countries. In addition, its relative influence is stronger for the Chinese economy.

TABLE II
RESULTS OF THE JOHANSEN CO-INTEGRATION TEST

China				
Unrestricted Co-integration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.790736	81.40346	47.85613	0.0000
At most 1	0.399302	28.22205	29.79707	0.0751
Unrestricted Co-integration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.790736	53.18141	27.58434	0.0000
At most 1	0.399302	17.32853	21.13162	0.1571
Nigeria				
Unrestricted Co-integration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.763864	76.66269	47.85613	0.0000
At most 1	0.408908	27.58883	29.79707	0.0880
Unrestricted Co-integration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.763864	49.07386	27.58434	0.0000
At most 1	0.408908	17.87663	21.13162	0.1345
USA				
Unrestricted Co-integration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.670699	87.99060	47.85613	0.0000
At most 1 *	0.521261	50.22394	29.79707	0.0001
At most 2 *	0.434962	25.17954	15.49471	0.0013
At most 3 *	0.156093	5.770235	3.841466	0.0163
Unrestricted Co-integration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.670699	37.76665	27.58434	0.0018
At most 1 *	0.521261	25.04441	21.13162	0.0133
At most 2 *	0.434962	19.40930	14.26460	0.0070
At most 3 *	0.156093	5.770235	3.841466	0.0163

In the short run, the income is only a significant driver of energy demand in USA and Nigeria while none of the explanatory variables influence energy demand in China. In addition, the coefficient of Nigeria's error term (-0.62) is significant and conforms to theoretical expectation. This implies that about 62 percent normalization takes place yearly if there is any shock. Therefore, the energy demand will be normalized within two years if there is any disequilibrium (as shown in Table III).

V. CONCLUSION

Numerous past studies have attempted to examine the drivers of energy demand. However, this paper adds to the existing research knowledge by investigate how the regional difference influences demand for energy in USA, Nigeria and China. The urbanization is used as a proxy to capture the regional features of the concerned countries. The estimated models reveal that income, urbanization and price are the key long-run drivers of energy demand in Nigeria, USA and China. However, in the short run, income insignificantly influences energy demand in Nigeria and USA. Furthermore, the impact of urbanization on China's energy demand is relatively stronger.

The policy implication of these findings is that long-run energy demand can effectively be managed in the three economies through focusing on energy prices, incomes and urbanization. For instance, policies toward reducing the urbanization rate such as improved social and economic amenities in rural areas, would influence the quantity of energy demand as a whole in the long run. However, more attentions on income are required to influence short-run energy demand in China. This implies that income-related policies could affect the consumption of energy.

VI. RECOMMENDATION

Low energy demand does not necessarily transcend to low economic growth, if argued from the perspective of energy efficiency, reduction in CO2 emission and energy waste. Based on the findings in this study, the following policy is recommended:

i. Reduction in the demand of fossil fuel through provision and subsidized program for renewable energy especially for those in the rural community who rely on wood fuel as their major source of cooking energy.
ii. Agriculture which is a major occupation for those in the rural area should be made a business sector rather than a way of life, through the provision of modernized farming program for rural communities.
iii. The true energy cost should be reflected on its consumption for people living in urban communities as a way of curtailing excess energy demand.
iv. Government should provide incentive for energy demand management especially for those living in urban areas.
v. Incentives should also be given to the industrial sector such as varying energy tariff for on and off-peak periods to encourage production during off peak periods which will in turn reduce cost of production.
vi. Reduce inflow of migrants from rural to urban communities through the provision of similar basic amenities available in urban areas and by providing an enabling commercial environment.

TABLE III
RESULTS OF THE VECM

Long-run Energy Demand Elasticities	China	Nigeria	United States of America
LNED(-1)	1.00	1.00	1.00
LNP(-1)	-0.19**	-0.01*	1.34***
	(-2.85)	(-1.53)	(8.20)
LNRGDP(-1)	-6.94***	-0.01	-0.27
	(-7.04)	(-0.29)	(-0.98)
LNU(-1)	80.72***	-0.21*	1.58***
	(6.41)	(1.63)	(3.90)
C	40.59	-6.701	-10.19
Short-run Energy Demand Elasticities	D(LNED_CH) China	D(LNED_NIG) Nigeria	D(LNED_USA) United States of America
Error Term	0.16	-0.62***	-0.06
	(1.67)	(-2.89)	(-0.66)
D(LNED(-1))	0.04	0.17	-0.38
	(0.16)	(0.90)	(-1.59)
D(LNED(-2))	-0.16	0.09	-0.20
	(-0.69)	(0.49)	(-0.95)
D(LNP(-1))	0.04	-0.01	0.33*
	(0.55)	(-1.08)	(1.97)
D(LNP-2))	0.07	-0.00	-0.10
	(0.79)	(-0.28)	(-0.62)
D(LNRGDP(-1))	-0.04	0.12***	0.65**
	(-0.08)	(2.45)	(2.22)
D(LNRGDP(-2))	1.19	0.01	0.01
	(1.47)	(0.12)	(0.03)
D(LNU(-1))	-9.34	0.07	7.50
	(-0.76)	(0.04)	(0.99)
D(LNU(-2))	0.46	-3.04	-7.40
	(0.04)	(-1.13)	(-0.91)
C	-0.00	0.06	-0.01
	(-0.03)	(1.58)	(-0.40)
R-squared	0.20	0.41	0.39
Adj. R-squared	-0.12	0.18	0.16

*, **, *** represents 10%, 5%, 1% significance levels respectively. T-statistics in ( ).

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