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Energy Consumption, Energy Prices and Economic Growth: Causal Relationships Based on Error Correction Model

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ABSTRACT

This study examined the Granger causality of energy consumption, oil price and economic growth in Nigeria. Two sub-categories of energy (kerosene and electricity) were equally considered. The error correction model framework was used to test the granger causality of the variables. The results for the total energy showed bidirectional causality between energy consumption and economic growth. As regards electricity, bidirectional causality was found between electricity consumption and economic growth as well as between electricity consumption and electricity price. No causal relationship exists among kerosene consumption, kerosene price and economic growth. Based on our findings, we recommend that policies that promote energy consumption and economic growth be introduced. One way of achieving this is through the adoption of appropriate energy pricing framework that takes cognisance of both the present and the future generation.

Keywords: Energy Consumption, Economic Growth, Kerosene Consumption, Electricity Consumption
JEL Classifications: C22, Q43, Q48

1. INTRODUCTION

The Nigerian economy has had a volatile "growth-history." From 1960 to 1970, the gross domestic product (GDP) recorded an annual growth of 3.1%. During the oil boom era (1970-78), GDP grew positively by 6.2% annually. However, negative growth rates were recorded in the 1980s. In the period 1988-1997 which constitutes the period of structural adjustment and economic liberalisation, the GDP grew at a positive rate of 4.0 (Ekpo and Umoh, 2004). GDP annual growth rate in Nigeria averaged 6.13% from 2005 to 2014, reaching an all-time high of 8.60% in 2010 and a record low value of 6.3% in 2012. According to Nigeria NBS (2014), the country's GDP advanced 7.67% in the last quarter of 2013.

Energy plays an important role in economic development (Glasure and Lee, 1997). Its output is being used in various forms (cooking, lighting, source of motive power for vehicles and other industrial equipment and machinery), which affects household and industrial activities in diverse ways. To achieve economic growth it is necessary to have access, at affordable prices, to abundant and different energy types, primarily commercial, which feed into the economic grid. An adequate, secure and affordable energy supply is thus needed to meet the needs of the business and domestic users, including the transport of people and goods. The required energy that is capable of stimulating growth can only be made available to economic agents if the right pricing strategy is adopted.

Economists have long believed that commodity prices serve adequately to guarantee efficient allocation and distribution of goods. For instance, Hayek (2009) argued that a free price system allows for economic coordination via the price signals that changing prices send. Price is seen as a label, a signal, a piece of information that is attached to the good and service traded. Choices about methods of production, amounts to be produced and consume are based on price information.

The results of studies that examined the causal relationships among energy consumption, energy prices and economic growth have been mixed as the method of their analysis also varied. Most of these studies adopted the Granger causality test (Kraft and Kraft, 1978; Akarca and Long, 1980; Yu and Hwang, 1984; Yu and Choi, 1985). In view of this, this paper evaluated the causal relationships among energy consumption, energy prices and economic growth based on the error correction model (ECM). A further rationale for this study stems from our consideration of the two sub-categories of energy consumption and prices: kerosene and electricity. Although Asafu-Adjaye (2000) incorporated price into his energy consumption and economic growth model, it was left at the aggregate level. Moreover, while he proxied the price of energy with Consumer Price Index, we adopted the actual prices of energy products in this study.

The remainder of this paper is structured in the following way. Section 2 presents a brief overview of the economic and energy use profiles of Nigeria. Section 3 centres on literature review whereas Section 4 briefly describes the theoretical framework and Methodology adopted. Section 5 presents and discusses the empirical results while section six concludes the study.

2. ECONOMIC AND ENERGY USE PROFILES

Figure 1 presents annual trend of GDP, oil price and energy consumption in Nigeria. It is evident that energy consumption has rapidly trended upward. From 36070.719 million kt in 1970, it stood at 113053.066 million kt in 2010. Percentage growth of GDP is riddled with high level of instability, depicting negative values in the years before 1984. Ever since then, it has been foot-dragging. Oil price clearly presents a different picture, for almost all the periods, it exhibited a random walk. It touched its peak in 2009 before reverting downward.

Figure 2 captures percentage growth of GDP, electricity consumption and electricity price. Electric power consumption stood at 1637 million kWh in 1971 and jived to 4997 million kWh in 1980, 8291 million kWh in 1990 and 9109 million kWh in 2000. It got to its all high value of 23542 million kWh in 2012. Electricity per kWh from 1970 to 1986 did not reach 50 kobo. It rose to 3 Naira, 24 kobo in 1995 and later came down to 1 Naira, 54 kobo in the following year. Beyond this period, it began to increase until it got to 8 Naira in 2012.

Figure 3 presents percentage growth of GDP, kerosene consumption and kerosene price. Kerosene consumption rose consistently from 1970 to 1988 (14.75 million L to 37.88 million L). From 1977 to 2012, it recorded its lowest value in 2004 (19.94 million L) and got to its peak in 2010 when it assumed an all high value of 38.92 million L. Before 1992, kerosene sold for <1 Naira/L. After this point, the price of kerosene has maintained a steady rise.

3. LITERATURE REVIEW

Kraft and Kraft (1978) found evidence in favour of causality running from gross national product (GNP) to energy consumption in the United States, using data for the period 1947-1974. Their findings were later reinforced by other studies. For instance, Akarca and Long (1979) established unidirectional Granger causality running from energy consumption to employment (their proxy for economic growth) with no feedback, using US monthly data for the period 1973-1978. They estimated the long-run elasticity of total employment relating to energy consumption to be −0.1356.

However, these findings of Kraft and Kraft (1978) and Akarca and Long (1979) have been subjected to empirical challenge. A number of studies that emerged afterwards found no causal relationships between income (proxied by GNP) (Akarca and Long, 1980; Yu and Hwang, 1984; Yu and Choi, 1985; and Erol and Yu, 1987a) and energy consumption. Regarding the causal relationship between energy consumption and employment, Erol and Yu (1987b, 1989) Yu et al. (1988) and Yu and Jin (1992) found evidence in favour of neutrality of energy consumption with respect to employment, evidence referred to in the literature as the "neutrality hypothesis."

Glasure and Lee (1997) tested for causality between energy consumption and GDP for South Korea and Singapore using the standard Granger test, as well as cointegration and error-correction modelling. The cointegration and error-correction modelling results indicated a bidirectional causality between income and energy for both countries. Conversely, using the standard Granger causality tests, they found no causal relationships between energy consumption and GDP for South Korea and a unidirectional Granger causality from energy consumption to GDP for Singapore.

Asafu-Adjaye (2000) estimated the causal relationships between energy consumption and income for India, Indonesia, the Philippines and Thailand, using cointegration and error-

Figure 1: Percentage growth of gross domestic product, oil price and energy consumption

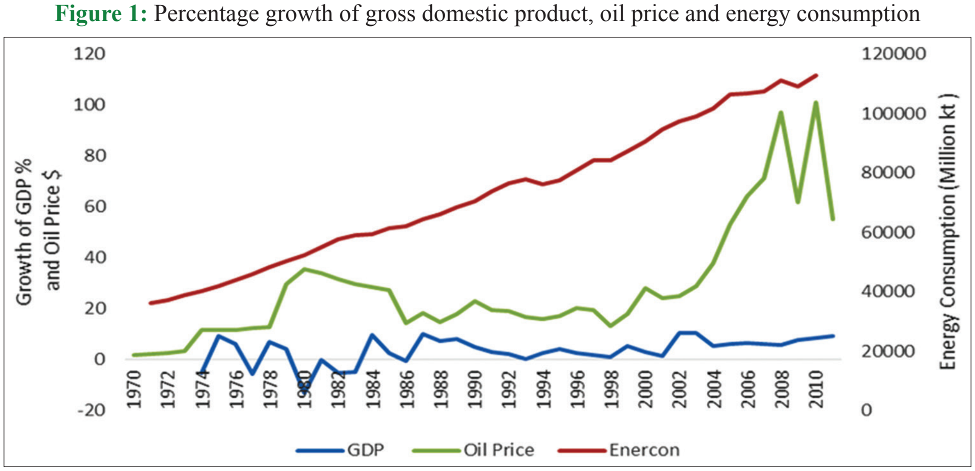


Figure 2: Percentage growth of gross domestic product, electricity price and electricity consumption

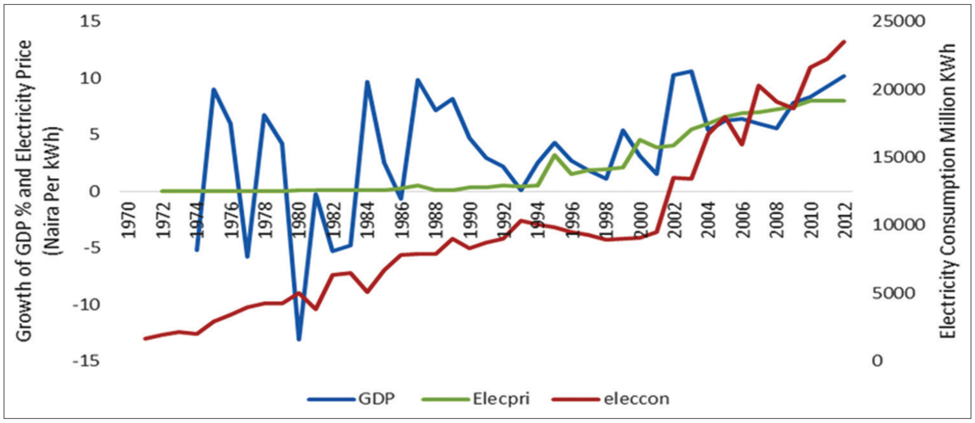
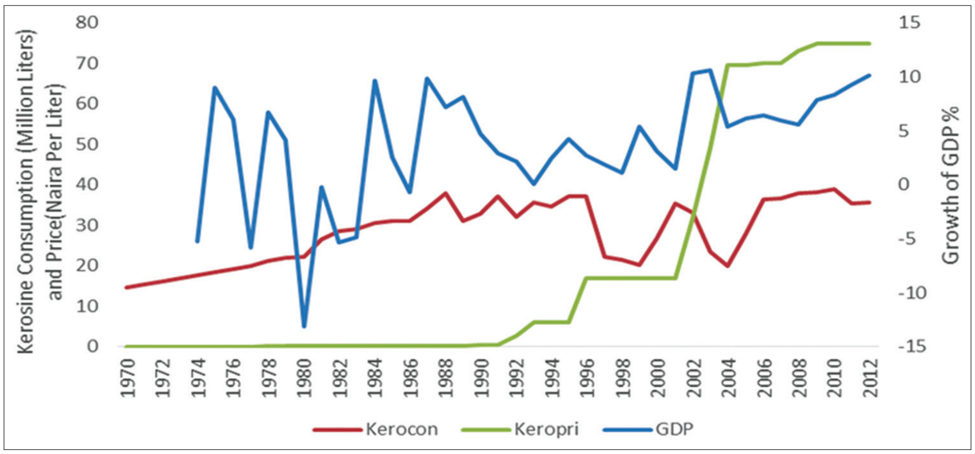


Figure 3: Percentage growth of gross domestic product, kerosene price and kerosene consumption



correction modelling techniques. The results of his study indicated that, in the short-run, unidirectional Granger causality runs from energy to income for India and Indonesia, while bidirectional Granger causality runs from energy to income for Thailand and the Philippines. In the case of Thailand and the Philippines, Asafu-Adjaye found that energy, income and prices are mutually causal. The study results do not support the view that energy and income are neutral with respect to each other, with the exception of Indonesia and India where neutrality was observed in the short-run. In a spate study, Al-Iriani (2006) applied panel analyses to investigate income and energy consumption relationship for the Gulf Cooperation Council countries for the period 1971-2002. His study was a foremost attempt towards bringing the major energy (oil) exporting countries into the mix of countries covered by this line of study. Al-Iriani found cointegration and unidirectional causality that flows from GDP to energy consumption.

Joyeux and Ripple (2007) employed state-of-the-art panel cointegration techniques to evaluate the nature of the relationship between income measures and energy consumption measures for seven East Indian Ocean countries. Their general finding was that income and household electricity consumption are not cointegrated. Given this finding, they conclude that standard of living measures that rely on income measures and do not include household-level energy consumption information will necessarily miss important indications of both levels and changes of standard of living.

Adeniran (2008) tested for causal relationship between energy consumption and GDP in Nigeria using systematic econometric techniques. The study found that there is a unidirectional causality that runs from GDP to electricity consumption. The study also found that GDP granger causes gas consumption. However, his analyses revealed no causality between oil consumption and GDP. In the aggregate, the study disclosed that energy consumption granger causes economic growth in Nigeria; implying that a policy to reduce energy consumption aimed at reducing greenhouse gas emissions is likely to have a detrimental impact on the nations GDP.

Rafiq and Salim (2011) examined the short- and long-run causal relationship between energy consumption and GDP of six emerging economies of Asia. Based on cointegration and vector error correction modelling the empirical results their study revealed that there exists unidirectional short- and long-run causality running from energy consumption to GDP for China, unidirectional short-run causality from output to energy consumption for India, whilst bi-directional short-run causality for Thailand. They found neutrality between energy consumption and income in the case of Indonesia, Malaysia and Philippines. In their study, both the generalized variance decompositions and impulse response functions confirmed the direction of causality. These findings, according to them, have important policy implications for the countries concerned. The results, they maintained, suggest that while India may directly initiate energy conservation measures, China and Thailand may opt for a balanced combination of alternative polices.

Kaplan et al. (2011) studied the causal relationship between energy consumption and economic growth for Turkey during 1971-2006. They employed two multivariate models, namely, demand model and production model, based on vector ECM. Then, they tested Granger causality after finding cointegration among variables for the both models. The results of their study indicated that energy consumption and economic growth are cointegrated and there is bidirectional causality running from energy consumption to economic growth and vice versa. This, according to them, means that an increase in energy consumption directly affects economic growth and that economic growth also stimulates further energy consumption. Consequently, they concluded that energy is a limiting factor to economic growth in Turkey and, hence, shocks to energy supply will have a negative impact on economic growth and *vice versa*.

Shaari et al. (2012) evaluated the relationship between energy consumptions and economic growth in Malaysia using data from 1980 to 2010. They Johansen co-integration was employed for the data analyses. Findings of their study showed that energy consumptions are related to economic growth. They used the Granger causality model to measure the causal effect of energy consumption and GDP. The results indicated that oil and coal consumption does not Granger cause economic growth and *vice versa.* Causality, according to the results of their study, runs from economic growth to electricity consumption. They also discovered that a unidirectional relationship exists between gas and economic growth, with causality running from electricity use to economic growth. They took the stand that a policy to reduce gas utilization will harm economic growth in Malaysia.

Abalaba and Matthew (2013) analysed the trend of energy consumption, real output, financial development, monetary policy rate and consumer prices and also examined the long-run relationship and direction of causality between energy consumption and economic growth with consideration for financial development, monetary policy rate and consumer prices. The result showed that all the variables used in the study are characterized by a positive trend. The study provided weak evidence in support of long-run relationship between energy consumption and economic growth. They concluded that energy consumption only has short-run positive impact on the economy but has not enhanced long-run economic growth in Nigeria during the period under investigation.

Naser (2014) empirically examined the relationship between oil consumption, nuclear energy consumption, oil price and economic growth in four emerging economies (Russia, China, South Korea, and India) over the period from 1965 to 2010. The results suggested that there is a unidirectional causality running from real GDP to oil consumption in China and South Korea, while bidirectional relationship between oil consumption and real GDP growth appears in India. Further, the results proposed that while nuclear energy stimulates economic growth in both South Korea and India, the rapid increase in China economic growth requires additional usage of nuclear energy. In 2015, he changed the focus of his study by examining the causal relationship between the same set of variables for four industrialised countries; the US, Canada, Japan, and France. The results showed that there is one-way causality from nuclear energy consumption to economic growth in Japan. Conversely, he found that increasing real GDP causes additional nuclear energy consumption in France. For the US and Canada, he found evidence that supported the neutrality hypothesis. Naser (2015) finally recommended that policies in the developed countries should endeavour to overcome the constrains on nuclear energy consumption to face any un-expected hikes in oil prices, which may adversely affect economic growth in such oil importing countries.

In an attempt to provide reasons for the disparate and often conflicting empirical findings on the relationship between energy consumption and economic growth, Asafu-Adjaye (2000) blamed it on the variety of approaches and testing procedures employed in the analyses. According to him, several studies employed simple log-linear models estimated by ordinary least squares without any regard for the nature of the time series properties of the variables involved. He recognised that most economic time series are non-stationary in levels form and as such, failure to account for such properties could result in misleading relationships among the variables. These challenges have been adequately addressed in this study.

4. THEORETICAL FRAMEWORK AND METHODOLOGY

4.1. Theoretical Framework

In view of the objectives of this paper and following Asafu-Adjaye (2000) we specify the inter linkage among energy consumption, energy price and economic growth. Aside the aggregate energy consumption and price analysis, this paper also considers two sub-categories of energy consumption and prices: kerosene and electricity.

4.2. Methodology

The Granger causality test within an ECM framework was used to estimate the inter-linkage among the variables. The ECM specification was used given that the variables were integrated of order one (1) and were as well cointergrated.

Starting with aggregate energy consumption, oil price and economic growth, we have:

$$\Delta grgdp_t = \alpha_1 + \alpha_2 \Delta enrcon_{t-1} + \alpha_3 \Delta oilp_{t-1} + \alpha_4 ecm1_{t-1} + \xi_{1t} \quad (1)$$

$$\Delta enrcon_t = \alpha_1 + \alpha_2 \Delta grgdp_{t-1} + \alpha_3 \Delta oilp_{t-1} + \alpha_4 ecm1_{t-1} + \xi_{2t} \quad (2)$$

$$\Delta oilp_t = \alpha_1 + \alpha_2 \Delta enrcon_{t-1} + \alpha_3 \Delta grgdp_{t-1} + \alpha_4 ecm1_{t-1} + \xi_{3t} \quad (3)$$

Then electricity consumption, electricity price and economic growth:

$$\Delta grgdp_t = \beta_1 + \beta_2 \Delta kercon_{t-1} + \beta_3 \Delta kerpr_{t-1} + \beta_4 ecm1_{t-1} + \psi_{1t} \quad (4)$$

$$\Delta kercon_t = \beta_1 + \beta_2 \Delta grgdp_{t-1} + \beta_3 \Delta kerpr_{t-1} + \beta_4 ecm2_{t-1} + \psi_{2t} \quad (5)$$

$$\Delta kerpr_t = \beta_1 + \beta_2 \Delta kercon_{t-1} + \beta_3 \Delta grgdp_{t-1} + \beta_4 ecm3_{t-1} + \xi_{3t} \quad (6)$$

For kerosene consumption, kerosene price and economic growth:

$$\Delta grgdp_t = \delta_1 + \delta_2 \Delta elecon_{t-1} + \delta_3 \Delta elepr_{t-1} + \delta_4 ecm1_{t-1} + \zeta_{1t} \quad (7)$$

$$\Delta elecon_t = \delta_1 + \delta_2 \Delta grgdp_{t-1} + \delta_3 \Delta elepr_{t-1} + \delta_4 ecm2_{t-1} + \zeta_{2t} \quad (8)$$

$$\Delta elepr_t = \delta_1 + \delta_2 \Delta elecon_{t-1} + \delta_3 \Delta grgdp_{t-1} + \delta_4 ecm3_{t-1} + \xi_{3t} \quad (9)$$

where, grgdp is economic growth, enrcon is aggregate energy consumption, oilp is crude oil price, kercon is kerosene consumption, kerpr is kerosene price, elecon is electricity consumption, elepri is electricity price and ecm is the error-correction model.

The ECM opens an additional causality channel which is overlooked by the standard Granger (1969) and Sims (1972) testing procedures. In the Granger sense a variable X causes another variable Y if the current value of Y can better be predicted by using past values of X than by not doing so. The Granger causality testing procedure involves testing the significance of the conditional on the optimum lags.

The Granger causality of the dependent variables was tested as follows: (1) by a simple t-test of the coefficients of the ecm; (2) by a joint Wald F-test of the significance of the sum of the lags of each of the explanatory variables in turn; and (3) by a joint Wald F-test of the interaction of the coefficients of ecm with corresponding variables in the models. The annual time series for Nigeria cover the period 1970 and 2012. The data were sourced from World Development Indicators 2013 and from the energy regulatory agencies.

Variable are defined thus:

grgdp: Growth rate of GDP (%).

enrcon: Commercial energy use, (kt of oil equivalent).

oilp: Price of barrel of crude oil.

Kercon: Litters of kerosene.

kerpr: Price of kerosene per litter.

elecon: Electricity consumption is measured with electric power consumption (kWh).

elepri: Price of electricity per kWh.

5. EMPIRICAL ANALYSIS

Reported in Table 1 is the result of both ADF and PP test for stationary of the variables. It shows that the null hypothesis of nonstationarity cannot be rejected at the 5% level for the variables levels. When the first differences of the variables were taken, the null hypothesis of nonstationarity was rejected for all the variables (Table 1).

The two methods of unit root test were adopted in order to establish consistency in the results generated. Since all the variables were integrated of order one, I(1), we proceeded to test for cointegration using the Johansen cointegration test (Table 2). Table 2 shows that in the aggregate energy model, the null hypothesis of no cointegration relationships was rejected against the alternative of two cointegrating relationships at the 1% level. Similar results were obtained in the case of kerosene and an electricity model, as the null hypotheses of no cointegration relationship among the variables was again rejected against the one cointegrating relationship.

The existence of cointegrations among energy consumption, energy prices and economic growth was suggestive of at least one direction Granger causality among the variables. This however would not indicate the direction of the temporary causality. The ECM results would then be required to indicate the direction of causation as well as in identifying the differences between the long-run and short-run Granger causality.

Presented in Table 3 is the joint Wald F-statistics of the lagged explanatory variables of the ECM. The results show that there were short-run causal effects among the variables. Also provided is the t-statistics for the coefficients of the ECMs which give an indication of long-run causal effects. The joint Wald F-statistics for the interactive terms, that is, the ECM and the explanatory

Table 1: Results of the unit root tests

Variables	Augmented dickey fuller (ADF)		Phillips Perron (PP)		
	Levels	First differences	Levels	First differences	
grgdp	−2.581	−10.505	−3.181	−11.731	I (1)
Aggregate energy variable					
enrcon	−2.489	−6.130	−2.341	−6.136	I (1)
oilp	−2.278	−11.175	−1.637	−10.379	I (1)
Kerosene variable					
kercon	−2.523	−5.739	−1.928	−8.648	I (1)
kerpr	−0.188	−3.574	0.614	−3.397	I (1)
Electricity variable					
elecon	−1.975	−6.066	−1.949	−8.719	I (1)
elepr	0.995	−8.502	0.977	−8.707	I (1)

Table 2: Results of Johansen's cointegration test (intercept, no trend)

Hypothesized	Eigenvalue	Trace statistic	5% critical value	*P***
Aggregate energy model				
None*	0.477879	38.04101	29.79707	0.0045
At most 1*	0.406701	17.24562	15.49471	0.0270
At most 2	0.016727	0.539783	3.841466	0.4625
Trace test indicates 2 cointegrating eqn (s) at the 0.05 level				
Kerosene model				
None*	0.475294	31.83208	29.79707	0.0287
At most 1	0.249427	11.83967	15.49471	0.1648
At most 2	0.090633	2.945207	3.841466	0.0861
Trace test indicates 1 cointegrating eqn (s) at the 0.05 level				
Electricity model				
None*	0.477385	33.80661	29.79707	0.0164
At most 1	0.251849	10.44584	15.49471	0.2480
At most 2	1.19E-05	0.000429	3.841466	0.9853

Trace test indicates 1 cointegrating eqn (s) at the 0.05 level. *Denotes rejection of the hypothesis at the 0.05 level

Table 3: Causality between energy consumption, energy price and economic growth of using ECM framework

Dependents variables	Short-run effects Wald F-statistics			Sources of causation t-ratio	Wald F-statistics		
Total energy	**grgdp**	**enrcon**	**oilp**	**ect[1] only**	**grgdp**	**enrcon**	**oilp**
grgdp	-	8.61**	1.45	−3.21**	-	4.19**	3.49
enrcon	7.34**	-	0.34	−1.29	3.92**	-	0.37
oilp	1.52	1.40	-	−1.26	0.76	0.89	-
Kerosene	**grgdp**	**kerocon**	**keropr**	**ect only**	**grgdp**	**kerocon**	**keropr**
grgdp	-	1.87	1.87	1.90	-	2.41	4.71
kerocon	1.74	-	0.65	1.56	3.71	-	1.79
keropr	0.17	0.41	-	−1.89	4.00	1.69	-
Electricity	**grgdp**	**eletcon**	**elecpr**	**ect only**	**grgdp**	**elctcon**	**elecpr**
grgdp	-	12.1***	1.20	−2.17**	-	12.9**	0.21
elctcon	5.23**	-	7.67**	−3.92**	4.43**	-	1.23
elecpr	0.45	4.51**	-	−3.78**	1.90	2.38	-

ECM: Error correction model, [1]: ECT-error correction term in the error-correction model. Significance at the UUU1% level, the 0.05% leveland the 0.10% level. *, **, ***represents 0.10, 0.05 and 0.01

variables is also captured in the models. This indicated that the variables bear the burden of short-run adjustment to re-establish long-run equilibrium.

Starting with the short-run result of the total energy (Table 3), it showed that the F-statistics for energy (in the economic growth equation) was significant. Similarly, the F-statistics of economic growth (in the energy consumption equation) was equally significant in both short and long-run. The result implied that there was bidirectional Granger causality between economic growth and energy consumption. Also indicated in the result was the fact that oil price had a neutral effect on both energy consumption and economic growth. For kerosene, the result showed that there was no causal relationship among grgdp, kerocon and keropr. Moreover, none of the interactive terms were statistically significant, implying that the long-run relationship among kerosene consumption, kerosene price and economic growth were weak.

The economic growth equation indicated that electricity consumption granger-causes economic growth in both short-run and long-run while the electricity consumption equation showed that economic growth granger-cause electricity consumption. This indicated bidirectional granger causality. This result further revealed that price of electricity granger causes electricity consumption in the same way that electricity consumption granger causes the price of electricity.

6. CONCLUSION

This study examined the Granger causality of energy consumption, oil price and economic growth in Nigeria. Two sub-categories of energy (kerosene and electricity) were as well considered. The ECM framework was used to test for the granger causality among the variables. The results showed for the total energy equations, bidirectional causality between energy consumption and economic growth. As regards electricity, bidirectional causality was discovered between electricity consumption and economic growth. Similarly there was bidirectional causality between electricity consumption and electricity price. No causal relationship was dictated among kerosene consumption, kerosene price and economic growth. In general, the study does not support the hypothesis of a neutral relationship between energy and economic growth, except for kerosene.

Based on the findings, we therefore, recommend that policies that promote energy consumption and economic growth be introduced. One way of achieving this is through the adoption of appropriate energy pricing framework that takes cognisance of both the present and the future generation.

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