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Fossil Fuel, Renewable Energy, Global Warming and Nigerian Economic Growth: A Causal Inference

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Abstract
The study examines the causality between sources of primary energy consumption, carbon dioxide emission and Nigerian economic growth using annual times series data for the period 1971 to 2013. The Toda-Yamamoto Granger causality approach was employed to establish the pattern and direction of causality. The results supported the growth hypothesis for Nigeria with respect to fossil fuel and combustible energy consumption while feedback hypothesis is supported with respect to non-combustible energy consumption. It also suggests that current level of primary energy consumption sources do not Granger cause global warming. The study recommends adopting a sustainable, expansive energy use strategy and diversifying further into the use of cleaner alternative sources of energy to promote economic, environmental and healthy well-being.
Keywords: Fossil fuel, Carbon dioxide emission, Renewable, Causality, Economic growth, VAR

1. Introduction

The correlation between energy consumption and economic growth has long been established by numerous past studies, but interest has shifted to the direction of causality over the past few decades. This is in response to increasing concern to combat global climate change through reduction in aggregate energy consumption especially fossil fuel. This clearly has important policy implication for both heavily industrialized nations as well as developing economies like Nigeria that depend a lot on fossil fuel for domestic consumption, and its sales to finance government budgetary expenditure. The empirical findings from past studies tried to establish evidence in support of either growth, conservation, feedback or neutrality hypothesis.

Majority of the country specific empirical studies for Nigeria measured energy consumption using electricity, total aggregate energy consumption or components of fossil fuel such as coal, natural gas and petroleum. Some studies tested causal pattern using traditional Granger causality. Therefore, this paper will contribute to the empirical literature by using fossil fuel, combustible renewable and non-combustible renewable as measures of energy consumption while Carbon dioxide gas (CO_2) emission is used as a proxy for global warming in the causality model. The paper will also adapt the Granger causality test based on the Toda and Yamamoto (1995) approach which has been supported by several studies to be more robust for analysing causality pattern.

2. Literature Review

Energy consumption sources can be primary (occurring naturally) or secondary such as electricity. Primary sources of energy can be classified into combustible, non-combustible (alternative energy) resources and fossil fuel (non-renewable energy). Secondary sources like electricity can be produced from different primary sources. Examples of combustible resources comprise of biofuel, industrial waste and biomass products such as fuel wood and animal waste. Several studies (Aina & Odebiyi, 1998; Mustapha & Fagge, 2015; Simonyan & Fasina, 2013) suggest that combustible renewables in the form of traditional biomass and waste account for more than 70 percent of primary energy consumption in Nigeria. This is largely driven by household (residential) demand especially in rural areas and agricultural sector consumption, thereby making the household sector a major contributor of carbon dioxide emission.

Non-combustible (alternative) energy comprises of geothermal energy, solar, wind, hydro, tide and wave. The absence of carbon dioxide gas (CO_2) in non-combustible renewable differentiates it from other sources of energy. Numerous studies (Jiang, Xiao, Kuznetsov, & Edwards, 2010; Kerr, 1992; Nisbet & Myers, 2007; Schelling, 1992; Warrick & Farmer, 1990) suggest that CO_2 gas is a major contributing agent of global warming. The use of non-combustible renewable has gained popularity particularly in developed countries due to growing concerns of climate change, and in Nigeria due to the need to diversify the primary source of electricity generation. There is also growing concerns of securing sustainable gas supply to power plants from the restive Niger Delta region. Gujba, Mulugetta, & Azapagic (2011) argued that the adaptation of non-combustible renewable is rather slow given the high set-up cost, vast quantities of relatively cheap fossil fuel reserve and lack of cohesive environmental policy that sets emission target to reduce environmental pollution by indigenous multinational oil companies operating in Nigeria.

Fossil fuel (non-renewable) energy comprises mainly of coal, petroleum and natural gas. Nigeria has the second largest proven oil reserve in Africa and ninth largest in terms of world natural gas reserve holding (E.I.A.

2016). Despite having a large low-sulphur coal reserve in excess of 2,000 billion tonnes (Fatoye & Gideon, 2013; Mustapha & Fagge, 2015), numerous studies (Gbadebo & Okonkwo, 2009; Ikhide & Adjasi, 2015; Oyaromade, Mathew, & Abalaba, 2014) have argued that coal consumption has significantly declined over the past few decades in favour of petroleum (for transportation) and natural gas (for electricity generation). Odumugbo (2010) and Oseni (2011) suggest that more than 80% of power plants for electricity generation in Nigeria utilise natural gas technology. The objectives to stimulate investment in the Nigerian gas sector with the aim to eliminate gas flaring provided an important basis for promoting gas based power plants in Nigeria for electricity generation. However, the Nigerian Electricity Regulatory Commission (NERC) has been pushing for diversification in the energy generation mix in response to incessant unrest in the gas rich Niger Delta Region, and partly due to the failure of gas laws in Nigeria to eliminate gas flaring.

The results of empirical findings in the past on the causality between energy consumption and economic growth have been mixed supporting either the growth, conservation, feedback or neutrality hypothesis. The variation in empirical findings is due to differences in methodology, estimation techniques, time-periods, data frequency as well as country specific characteristics. The most common econometric techniques utilised for most country specific studies is based on either Granger's (1969) or Sim's (1972) Granger causality approach, Johansen and Juselius (1990) cointegration, ARDL bounds testing and Toda-Yamamoto's (1995) VAR approach for testing causality. Most cross-country studies applied panel cointegration and error correction models to analyse causal relationships.

The growth hypothesis supports unidirectional causality running from energy consumption to economic growth. The policy implication here is that shortages in energy supply or environmental regulations such as tax increases meant to reduce energy consumption will affect economic output negatively and vice versa. Given the high degree of industrialization in most developed and emerging economies, some studies (Amiri & Zibaei, 2012; Stern, 1993) have found evidence in support of the growth hypothesis for developed economies and numerous other studies (Altinay & Karagol, 2005; Khan & Qayyum, 2007; Lee & Chang, 2008; Shaari, Rahib, & Rashid, 2013; Shiu & Lam, 2004; Tiwari, 2011) found evidence for emerging market economies. Likewise, several studies (Adebola, 2011; Apergis & Payne, 2009; Atif & Siddiqi, 2010; Ouedraogo, 2013) also found evidence for the developing economies.

Among the studies for Nigeria that support the growth hypothesis, Orhewere and Henry (2011) used annual time series data (1970-2015) and applied VECM based Granger causality test. The results found evidence in support of growth hypothesis with respect to electricity and gas consumption in the short run, and oil consumption in the long run. Similarly, Ikhide & Adjasi (2015) applied ARDL bounds testing approach on quarterly time series data (1971 to 2013) for Nigeria. The findings supported the growth hypothesis for renewable energy consumption and conservation hypothesis for non-renewable energy consumption.

The Conservation hypothesis indicates unidirectional causal flow from economic growth to energy consumption. The implication here is that reduction in energy consumption will not have significant impact on economic growth. Several studies (Hatemi & Irandoust, 2005; Kraft & Kraft, 1978; Menyah & Wolde-Rufael, 2010) found evidence for developed countries, other studies (Chiou-Wei, Chen, & Zhu, 2008; Ghosh, 2002; Lise & Montfort, 2007; Sadorsky, 2009) for emerging economies, and some studies (Adom, 2011; Hye & Riaz, 2008) supported the conservation hypothesis for developing countries.

In a country specific study, Akinwale, Jesuleye, & Siyanbola, (2013) established evidence in support of the conservation hypothesis for Nigeria using vector auto regressive (VAR) and error correction model (ECM) for the period 1970-2005. Likewise, Adeniran (2009) used time series data (1980-2006) for variables of coal and electricity consumption, and the results also supported the conservation hypothesis.

The feedback hypothesis indicates a two-way causal flow between energy consumption and economic growth. The policy implication here is that economic growth and energy consumption influence one another. A notable number of country specific and cross-country studies (Bartleet & Gounder, 2010; Belke, Dobnik, & Dreger, 2011; Fuinhas & Marques, 2012; Gurgul & Lach, 2011; Shahbaz, Tang, & Shabbir, 2011) found support for developed economies, and several other studies (Aslan, 2014; Loganathan & Subramaniam, 2010; Nazlioglu, Kayhan, & Adiguzel, 2014; Ozturk, Aslan, & Kalyoncu, 2010) for emerging economics, and many others (Eggoh, Bangake, & Rault, 2011; Jumbe, 2004; Kahsaia, Nondob, Schaefferc, & Tesfa, 2011; Shahbaz, Loganathan, Zeshan, & Zaman, 2015) for the developing economies.

In a cross-county study for Tanzania and Nigeria for the period 1960 to 1984, Ebohon (1996) established support for the feedback hypothesis. Similarly, Ogundipe and Apata (2013) applied Johansen cointegration technique and pair-wise Granger causality on Nigerian data (1980-2008). The findings supported bidirectional causality between electricity consumption and economic growth. Moreover, Oshota (2014) used time series data for Nigeria (1970-2011) and applied ARDL bounds testing approach. The results found evidence of cointegration and the VECM Granger causality test supported the feedback hypothesis in the long run.

The neutrality hypothesis suggests no evidence of causal flow in either directions between energy consumption and economic growth. As such, energy expansion or conservation policies will have no effect on economic output. Diverse studies (Fatai, Oxley, & Scrimgeour, 2004; Huang, Hwang, & Yang, 2008; Menegaki, 2011; Payne, 2009; Vaona, 2012; Yu & Choi, 1985) found support for developed economies, various other studies (Ozturk & Acaravci, 2010; Yalta & Cakar, 2012) for emerging economics and some studies (Esso, 2010; Wolde-Rufael, 2006) for the developing economies.

In a cross-country study for seven African countries using time series data (1970-2007), Esso (2010) applied threshold cointegration technique. The findings supported the neutrality hypothesis for Nigeria, Cameroun, South Africa and Kenya, the feedback hypothesis for Ivory Coast and the conservation hypothesis for Congo and Ghana. Additionally, Oyaromade et al. (2014) used time series data (1970-2010) for Nigeria and the results supported the neutrality hypothesis of no causal flow between energy consumption and economic growth. Similarly, Mustapha and Fagge (2015) applied VECM based Granger causality test using time series data (1980-2011) for Nigeria. The findings also supported the neutrality hypothesis between total energy consumption and economic growth.

As a result, several country specific studies for Nigeria did not explore the causal pattern with respect to the primary energy sources of combustible and non-combustible renewable. This is especially relevant given the aggressive efforts (through tax related incentives) introduced by the Nigerian government in recent years to stimulate investment in renewable energy particularly in the power generating segment of the electricity supply industry. These was in response to the eminent failure of the power sector reform introduced in the year 2005 to propel investment in fossil fuel especially gas based power plants. The incessant pipeline vandalism of gas networks in the Niger Delta region has created gas supply problems, and environmental pollution has been rising in host communities due to oil and gas exploration activities. This paper seeks to expand on the empirical literature by analysing the causality between fossil fuel, combustible renewables, non-combustible renewables, carbon dioxide gas (CO_2) emission and Nigerian economic growth.

3. Data and Methodology

The study used annual time series data for the period 1971-2013 obtained from World Bank Group for the dependent variable of real gross domestic product (RGDP) and independent variables of fossil fuel (FF), combustible renewable (CR), non-combustible renewable (NCR) and carbon dioxide gas (CO_2) emission. The RGDP is used as a proxy for economic growth and is measured in 2010 constant U.S dollars while the independent variables of FF, CR, and NCR are measured as a percentage of total energy consumption. CO_2 emission is measured in kiloton and is used as a proxy for global warming.

3.1 Order of Integration and Optimal Lag Selection

The Toda and Yamamoto (1995) Granger non-causality approach requires determining the maximum order of integration (d_{max}) among model variables, and the optimal lag order (k) before applying the VAR non-Granger causality test. Hence, this study adopts the Augmented Dicky fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests to determine the maximum order of integration while the Final Prediction Error (FPE), Hannan-Quinn Information Criterion (HQIC), Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) is used to determine the optimal lag length. However, the optimal lag length (k) given by the information selection criterion will be adjusted if there is need to achieve serial independence of the residuals and dynamic stability of the model.

3.2 Cointegration

Although the result of the Toda-Yamamoto Granger non-causality approach does not depend on the cointegration test, it nonetheless helps to provide information on the long-run relationship among variables having the same order of integration. It also helps to serve as a useful check for the non-Granger causality test since at least a unidirectional causality will be expected between variables found to be cointegrated. Therefore, the study will adopt the Johansen and Juselius (1990) maximum likelihood cointegration technique.

3.3 Toda-Yamamoto Granger Causality

The Toda and Yamamoto (1995) approach adopted in the study uses a modified Wald test which is based on an augmented level VAR. It has been found to be more robust since it ensures that the non-Granger causality test follows a standard asymptotic distribution of the Wald statistic irrespective of the integration and cointegration properties of model variables. The set of equations used for testing non-Granger causality in the Toda and Yamamoto approach is given by equations 1–5.

$$LRGDP_t = \varphi_1 + \sum_{i=1}^{k+dmax} \lambda_{1i} LRGDP_{t-1} + \sum_{i=1}^{k+dmax} \delta_{1i} FF_{t-1} + \sum_{i=1}^{k+dmax} \Psi_{1i} CR_{t-1} + \sum_{i=1}^{k+dmax} \Phi_{1i} NCR_{t-1} + \sum_{i=1}^{k+dmax} \gamma_{1i} CO2_{t-1} + \mu_{1t} \quad (1)$$

$$FF_t = \varphi_2 + \sum_{i=1}^{k+dmax} \lambda_{2i} LRGDP_{t-1} + \sum_{i=1}^{k+dmax} \delta_{2i} FF_{t-1} + \sum_{i=1}^{k+dmax} \Psi_{2i} CR_{t-1} \quad (2)$$

$$+\sum_{i=1}^{k+dmax} \Phi_{2i} NCR_{t-1} + \sum_{i=1}^{k+dmax} \gamma_{2i} CO2_{t-1} + \mu_{2t}$$

$$CR_t = \varphi_3 + \sum_{i=1}^{k+dmax} \lambda_{3i} LRGDP_{t-1} + \sum_{i=1}^{k+dmax} \delta_{3i} FF_{t-1} + \sum_{i=1}^{k+dmax} \Psi_{3i} CR_{t-1} \quad (3)$$
$$+\sum_{i=1}^{k+dmax} \Phi_{3i} NCR_{t-1} + \sum_{i=1}^{k+dmax} \gamma_{3i} CO2_{t-1} + \mu_{3t}$$

$$NCR_t = \varphi_4 + \sum_{i=1}^{k+dmax} \lambda_{4i} LRGDP_{t-1} + \sum_{i=1}^{k+dmax} \delta_{4i} FF_{t-1} + \sum_{i=1}^{k+dmax} \Psi_{4i} CR_{t-1} \quad (4)$$
$$+\sum_{i=1}^{k+dmax} \Phi_{4i} NCR_{t-1} + \sum_{i=1}^{k+dmax} \gamma_{4i} CO2_{t-1} + \mu_{4t}$$

$$CO2_t = \varphi_5 + \sum_{i=1}^{k+dmax} \lambda_{5i} LRGDP_{t-1} + \sum_{i=1}^{k+dmax} \delta_{5i} FF_{t-1} + \sum_{i=1}^{k+dmax} \Psi_{5i} CR_{t-1} \quad (5)$$
$$+\sum_{i=1}^{k+dmax} \Phi_{5i} NCR_{t-1} + \sum_{i=1}^{k+dmax} \gamma_{5i} CO2_{t-1} + \mu_{5t}$$

In the set of equations (1-5), $\varphi, \lambda, \delta, \Psi, \Phi$ and γ are model parameters while *LRGDP, FF, CR, NCR* and *CO2* stand for variables of logged real gross domestic product, fossil fuel, combustible, non-combustible renewable and carbon dioxide gas emission respectively. K is the optimal lag length and d_{max} is the maximum order of integration. The symbol μ_t is the model uncorrelated error term for each system equation.

4. Empirical Results and Interpretation

4.1 Unit Root Test and Optimal Lag Selection

The order of integration among model variables was established using the ADF and KPSS unit root tests. The results of the test are shown in table 1 and 2 respectively. Table 3 shows the result for the optimal lag selection using the FPE, AIC, SIC and HQ Information Criterion.

Table 1. Augmented Dickey Fuller (ADF) Unit Root Test

Variables	Level	5% Critical Value	First Difference	5% Critical Value	Remark
LRGDP	1.55	-2.93	-5.35*	-2.94	I (1)
FF	-3.32*	-2.93	-	-	I (0)
CR	-3.35*	-2.93	-	-	I (0)
NCR	-2.16	-2.93	-7.94*	-2.94	I (1)
CO2	-1.84	-2.93	-7.13*	-2.94	I (1)

Note: * denotes null rejection of non-stationarity at 5% level

Table 2. Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root Test

Variables	Level	5% Critical Value	First Difference	5% Critical Value	Remark
LRGDP	0.66*	0.46	0.40	0.46	I (1)
FF	0.36	0.46	-	-	I (0)
CR	0.36	0.46	-	-	I (0)
NCR	0.17	0.46	-	-	I (0)
CO2	0.47*	0.46	0.09	0.46	I (1)

Note: * denotes null rejection of stationarity at 5% level

The results from table 1 and 2 with the exception of NCR, both indicate that variables of FF and CR are stationary at level while variables of RGDP and CO2 are stationary after first differencing which suggest d_{max} to be 1. NCR is found to be first difference stationary by ADF test and level stationary by KPSS test. Hence, the level stationary variables would be excluded from the Johansen cointegration test. The ADF test is used to test the null hypothesis of non-stationarity while the KPSS test is use to test the null hypothesis of stationarity.

Table 3. VAR Lag Order Selection

Lag	FPE	AIC	SIC	HQIC
0	79.50410	18.56513	18.78061	18.64180
1	0.169218*	12.39950*	13.69233*	12.85948*
2	0.356482	13.07273	15.44292	13.91603
3	0.588073	13.37930	16.82685	14.60591
4	0.948072	13.44076	17.96567	15.05068
5	1.237467	12.87467	18.47694	14.86792

Note: * denotes optimum number of lags

The results from table 3 shows that the three Information criteria suggest lag 1 for the optimal lag length (k). However, the optimal lag will be increased to 2 since the residuals are found to be serially independent when the lag is increased to 2 at 10% significance level. The model is also found to be stable since all inverse roots of the characteristic AR polynomial lie inside the unit circle. As such, the optimal lag length used in testing the non-Granger causality, VAR [k + d_{max}] is equal to 3.

4.2 Cointegration Test

The variables of RGDP and CO2 that have the same integration I (1) in both KPSS and ADF unit root test are subjected to the Johansen Cointegration test and the results is shown in table 4.

Table 4. Johansen's Cointegration Test

Vector		Trace Statistics	Critical Value	Prob.	Max-Eigen Statistics	Critical Value	Prob.
H_o	H_1	λ_{trace}	5%		λ_{max}	5%	
r = 0	r >0	10.35123	15.49471	0.2547	8.912894	14.26460	0.2935
r <= 1	r >1	1.438334	3.841466	0.2304	1.438334	3.841466	0.2304

Note: r is number of cointegrating vector(s)

The trace and Max-Eigen statistics in table 4 indicate the absence of cointegration among the two variables. As such, it suggests the absence of a long run relationship. The null hypothesis of no cointegration cannot be rejected for both trace and Max-Eigen statistics at 5% level.

4.3 Toda-Yamamoto Granger Non-Causality Test

The results of the Wald test for Granger non-causality for the augmented level VAR [k + d_{max}] represented by the set of system equations 1-5 from section 3.3 is given in table 5. Each system equation is used to test Granger non-causality.

Table 5. Toda-Yamamoto Granger non-causality (Modified Wald) Test Results

	InRGDP	FF	CR	NCR	CO2
InRGDP	_	[0.9389]	[0.9476]	[0.0970]**	[0.2729]
FF	[0.0528]**	_	[0.9074]	[0.1355]	[0.7719]
CR	[0.0530]**	[0.9223]	_	[0.1354]	[0.7744]]
NCR	[0.0665]**	[0.9437]	[0.9073]	_	[0.7703]
CO2	[0.3249]	[0.9500]	[0.9325]	[0.551]	_

Note: * and ** denotes null rejection at 5% and 10% level

The result from table 5 indicates the presence of one way Granger causality running from fossil fuels, combustible and non-combustible renewable to Real GDP in support of the growth hypothesis for Nigeria at 10% level. This is also expected given the high level of fossil fuel consumption in the transportation and manufacturing sectors, combustible renewable by households, and increasing acceptability of non-combustible renewable for electricity generation largely propelled by policies adopted by the Nigerian Electricity Regulatory Commission (NERC) in recent years. The findings also agree with other studies (Orhewere & Henry, 2011; Ikhide & Adjasi 2015) that supported the growth hypothesis for Nigeria, but contradicted those studies (Akinwale et al., 2013; Adeniran, 2009; Ebohon, 1996; Ogundipe & Apata, 2013; Oshota, 2014; Esso, 2010; Oyaromade et al., 2014; Mustapha and Fagge, 2015) that supported the conservation, feedback and neutrality hypothesis for Nigeria. However, Fossil fuel, combustible and non-combustible energy consumption do not Granger cause carbon dioxide gas emission which implies that current level of energy consumption does not cause global warming. The results are not surprising given that energy consumption in Nigeria is dominated by combustible renewable which has lower carbon compounds than fossil fuel.

Moreover, the rate of carbon dioxide gas emission in Nigeria is relatively low when compared to some heavily industrialised nations of the world. Nonetheless, this should not discourage individuals, business owners and the Nigerian government from adapting more of alternative (non-combustible) renewable energy since the long run environmental and health benefits outweigh the short run cost. The results also supported bidirectional causality between non-combustible renewable energy consumption and economic growth.

5. Summary and Conclusion

The study analysed the causal pattern between real gross domestic product, fossil fuel, combustible and non-combustible renewable energy consumption and carbon dioxide gas emission in Nigeria using annual time series data for the period 1971 to 2013. The Johansen cointegration technique was applied to examine the long run relationship between variables and the Toda-Yamamoto Granger non-causality test approach to establish direction of causality.

The Findings of the Johansen cointegration test indicated absence of cointegration between variables of Real GDP and carbon dioxide gas emission. The outcome of the Toda-Yamamoto Granger non-causality test supported the growth hypothesis for Nigeria, thereby reinforcing the dependency of Nigerian Economic growth on energy usage. It also indicates that components of primary energy consumption in Nigeria do not Granger cause global warming which implies that current levels of carbondioxide gas emission might not be of serious concern, at least for the short term.

Although the findings suggest that fossil fuel does not Granger cause global warming, low cost cleaner sources of energy such as biodiesel should be promoted especially in the transportation sector since the long term environmental and health benefits outweigh the cost incurred in the short run.

Finally, the study recommends that the policies adapted by the Nigerian government towards promoting diversification into alternative (non-combustible renewable) sources of energy particularly for electricity generation should further be expanded. Private investment incentives should be increased to accommodate new entrants in the electricity supply industry by the Nigerian Electricity Regulatory commission (NERC).

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