On the relationship between energy consumption, productivity and economic growth: Evidence from Algeria, Ghana, Nigeria and South Africa

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11 May 2015

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Abstract

It has been suggested that Africa's growth is principally driven by natural resource rents. This is at variance with the growth in countries such as Korea and Taiwan where productivity has been identified as the main driver. In this study, the effect of energy consumption, investment, productivity on per capita growth in oil producing African countries is examined by employing a dynamic simultaneous panel data model. The simultaneous panel data model is able to examine the three-way causal relationship between energy consumption, productivity and economic growth. The results confirm the importance of income, productivity, price and investment influence the demand for renewable end non-renewable energy. The study recommends that there should be investment in productivity to enhance economic growth and minimize energy consumption.

KEY WORDS

Total Factor Productivity, Renewable Energy Consumption, Non-Renewable Energy Consumption, Economic Growth

1.0 Background

Energy is the oil that lubricates the engine of every economy. However, higher demand for energy through increased population and per capita growth has become a matter of concern for policy makers. Such an increment could threaten energy security and increase global warming since energy is major a contributor to the emission of CO2 (Bhattacharyya, 2011). There should be a balance between efficiency and reduction without compromising growth or the environment. In recent times, whilst economic growth has been a major goal, concerns about how such growth affects the environment have been predominant. This may lead to a force choice between fossil fuel and carbon neutral fuels such as renewable energy. Such a trade off, may affect both economic growth and environment. This calls for innovation and technological advances to make energy use efficient and reduce its impacts on the environment.

Ozturk (2010) surveys the literature on the energy –economic growth nexus and groups the findings under four main headings. First, the conservation hypothesis predicts a unidirectional causality from economic growth to energy consumption. This means that people acquire new electrical and other gadgets, drive more and use more energy when there is an increase in their income . Second, the growth hypothesis predicts a unidirectional causality running from energy consumption to economic growth. The proponents of this hypothesis identify energy as a key input of production. Energy therefore becomes a limiting factor to economic growth. Third, the neutral hypothesis postulates that there is no relation at all between energy consumption and economic growth. It has been argued that the cost of energy is relatively small as a proportion of GDP and cannot have a significant impact on economic growth (Ghali and EL-Sakka, 2004).

Fourth, the feedback hypothesis states that there is bidirectional causality between energy consumption and economic growth. This means a change in energy consumption have an effect on economic growth and vice versa. Energy is used to create economic value and value creation requires more energy.

The strong relation between energy productivity and capital use indicates that energy efficiency may be augmented by optimizing capital use (Zaman et al, 2011). This is because energy is not demanded for its own sake and does not produce output by itself. Energy works through capital stock and other mediums to contribute to output. Therefore, the efficiency of the capital stock enhances energy productivity. Energy productivity is essential to the environment and economic growth. First, it is the cheapest way to reduce global emission of green gases (Mckinsey, 2007).According to the IEA (2006), an additional dollar spent on more efficient electrical equipment, appliances or buildings systems avoids more than two dollars in investment in electricity. Secondly, energy saved through productivity measures can also be used in other sectors of the economy. Energy efficiency has been found to be one of the main ways of reducing the impact of the trade-off between reduction in energy consumption and economic growth. For instance, Dan (2002) finds that there has been a gradual decline in energy consumption in China since 1978 despite increasing growth and attributed this to energy efficiency. After the oil price shocks in 1973/74 and 1979/80, average productivity in energy use has increased due partly to the replacement of energy-inefficient capital with efficient ones (Berndt, 1990). The efficiency can be embodied in the capital or can be disembodied in the form of experience. Bendt (1990) asserts that as one operates a production process, experience is accumulated through learning which leads to a decreasing unit cost which is independent of the capital stock. He indicates further that, increase in energy productivity usually follow energy price shocks with considerable time lag. This means major changes in energy use can occur through learning and as the capital stock is replaced with more energy efficient ones.

According to Medlock (2011), economic structure and productivity are important determinants of energy demand. At the macro level, each of them influences energy intensity. As an economy develops, it moves from agriculture, to industry and to service. As the economy become service oriented, it requires less energy. Energy demand follows a bell-shaped trend as the economy moves from agrarian to service. Energy demand also depends on the decision to invest in capital stock, the type of capital stock, and the rate of utilization. As more energy efficient capital is deployed, the energy requirement for a given level of output declines, requiring less energy. This means that economic activity can be expanded without an increase in energy demand.

In summary, the relationship between energy consumption and economic growth is not conclusive. Further, Arbache and Page (2010) argue that Africa's growth after 1995 has been principally driven by natural resource rents. Again, O'connell and Ndulu (2000) suggest that the relatively low growth of Africa can be attributed to slow capital accumulation and slow productivity growth. Taking all this factors into consideration, this study examines the dynamic relationship between energy consumption, productivity growth, capital accumulation and economic growth in oil producing African countries. This study therefore examines the relationship between energy consumption, productivity and economic growth in selected African countries.

2.0 Literature Review

In Africa, few studies test the causal relationship between economic growth and energy consumption. One of such studies is Odhiambo (2009). He uses the ARDL bounds testing approach to examine the causal relationship between energy consumption and economic growth in Tanzania. The purpose of the study was to investigate the intemporal relationship between total energy consumption and economic growth and also examine the relationship between electricity consumption and economic growth. He uses real GDP growth as a proxy for economic growth and total energy consumption per capita and electricity consumption. The findings suggest that there is a stable long run relationship between energy and economic growth. Results from the causality test indicate a unidirectional causality running from energy consumption to economic growth. Electricity consumption Granger causes economic growth in the short run. The ARDL Cointegration approach has some distinct advantages over other cointegration techniques according to (Harris and Sollis, 2003). First, the ARDL does not impose restrictive conditions. This means that, it can be applied whether the variables are integrated in order one, order zero or partially integrated. Again, the ARDL generate a valid test statistics and unbiased long run estimates even if some of the variables are endogenous. This notwithstanding, Hamid et al (2010) argue that the assumption of ARDL restricts consideration to cases where there exists at most one cointegration equation between the variables. This is the major disadvantage of the ARDL approach to cointegration since ARDL estimation is valid only in the case of a single co integrating relation. In the event of more than one cointegration relation, ARDL estimation may not be valid .The ARDL becomes a model of choice only when the degree of integration of the variables cannot be ascertained. It has also been argued that the ARDL provides a low degree of freedom when it is used to estimate a regression with small sample size (Fatai et al, 2003).

Manyeh and Rufael (2010) expand the studies economic growth and energy consumption nexus in Africa by introducing pollutant emissions. They investigate the long run causal relationship between economic growth, pollutant emissions and energy consumption in South Africa for the period 1965 to 2006. Following Stern's study, they build a multivariate framework and introduce capital and labour in addition to energy consumption and GDP. They use the ARDL developed by Pearson et al (2001) is used to test the cointegration among the variables. They use the Toda and Yamamoto (1995) approach to estimate the long run causality between output capital, labour, CO^2 and energy consumption. The study finds an evidence of a short run and long run relationship among the variables. More specifically, the study finds a significant relationship between pollutant emissions and economic growth. The Granger causality test indicates a unidirectional causality running from energy consumption to economic growth, from energy consumption to CO^2 and from pollutant emissions to economic growth.

Yuan et al (2010) use the Grey incidence analysis to test the relationship between economic development and energy consumption in China at the Aggregate and disaggregate levels. China's development is divided into four main stages on the basis of political and economic events. GDP and value added of primary, secondary and tertiary industries are used as a proxy for economic development. Total consumption and the consumption of coal, crude oil, natural gas, wind power and hydropower are use to represent Chinese total energy consumption. The findings indicate a time-varying relationship between energy consumption and economic development. There is a high correlation between GDP and coal consumption. The study also finds a high correlation between secondary Industry and energy consumption. Though the study provides some useful recommendations for China, it fails to show the direction of causality which could have helped China's energy policy.

Contributing to the literature on the energy consumption- economic growth nexus, Tsani, (2010) uses the Toda and Yamamoto (1995) approach to study the causal linkages between energy consumption and economic growth in Greece. Further, he seeks to ascertain the level of energy consumption dependence of Greece and the pattern of energy consumption at the aggregate and disaggregate level. At the aggregate level, he found a unidirectional causality running from energy consumption to economic growth. However, the study finds a bidirectional relationship between industrial and residential energy consumption and economic growth. The neutral hypothesis is confirmed between transport energy consumption and economic growth. The methodology overcomes the problem of pretest bias by bypassing both cointegration and unit root pretest.

Bartleet and Gounder (2010) build two multivariate models to investigate the relationship and causality between economic growth and energy consumption in New Zealand from 1960 to 2004. First, they construct a demand model with GDP, energy prices and energy consumption. Then, they construct a production function with labour, capital, energy consumption and employment. The long run estimation of the demand model indicates a cointegration relationship GDP, energy prices and energy consumption. The short run analysis suggests that GDP Granger causes energy consumption.

The Toda and Yamamoto (1995) method of VAR and the Vector Error Correction Model (VECM) are applied to investigate the evidence of cointegration and causality between energy consumption and economic growth in Australia. Shahiduzzaman and Alam (2012) use a multivariate model to estimate a single sector production function for five decades. Following the work of Stern (2000), they include energy, capital and labour as different inputs in the production function. Like Stern (2000), employment rate was used as a proxy for both Capital and labour. They find a long run relationship between capital, labour, and energy. When the thermal energy aggregation was used, they find a weak causality between energy consumption and economic growth. However, when the quality adjusted energy aggregation is introduce; strong bidirectional causality was found between energy consumption and economic growth.

There are varied conclusions on the energy consumption and economic growth relationship in Africa Countries. Most of the studies concentrate on electricity consumption and economic growth and most of the study use bivariate models. For example, Adom (2011) investigates the relationship between economic growth and electricity consumption Ghana. He uses the Toda and Yamamoto (1995) approach to test and estimate the relationship between electricity consumption and economic growth from 1971 to 2008.The results indicate a unidirectional causality running from economic growth to energy consumption. Kwakwa (2011) examines the relationship and causality between disaggregated energy and economic growth, agricultural sector and the industrial (manufacturing) growth in Ghana from 1971 to 2007. Electricity and fossil fuels are used as proxies for energy consumption. Using the Johansen Cointegration test, he finds a unidirectional causality from overall growth and agriculture to fossil fuels and electricity consumption but bidirectional causality between manufacturing and energy consumption.

2.1 Renewable Energy Consumption, TFP and Economic Growth.

Renewable energy consumption minimizes environmental impact of energy consumption, improves stability and reliability of energy supply and enhances energy security (Voivontas et al 1998). It also helps countries meet emissions targets such as the one set up by the Kyoto Protocol and European Union. The World Bank (1999) has also indicated that renewable energy consumption improves access to clean and modern energy in rural areas which are connected to the national electricity grid. Despite these advantages, the consumption of renewable has not grown as compared other sources of energy. Painuly (2001) argued that the reasons for relative low growth in renewable energy are economic barriers such as high capital cost, market barriers and technological barriers. On cost, Stern (2007) has estimated that the economic impact of global warming could reduce global GDP by 25% whilst the mitigation of global warming through the use of renewables and efficiency cost 1% of global GDP. This 1% cost even represents initial investment.

There is empirical evidence that steady flow of technology influence sustainable economic growth positively (Aghion and Howitt, 1998). Again, energy efficiency improvements rely on the growth of TFP (Boyd and Pang, 2000). The debate has been the means through which such technologies are transmitted into economic growth and how they measured. Wilkins (2012) indicates that technology represents the bigger cost of renewable energy development and that, most developing economies like the ones in Africa do not have access to such technologies. This study is therefore necessary to ascertain the contribution of renewable energy to economic growth and to guide policy makers and businesses to invest more in renewable energy technology since more usage will drive down cost.

Renewable energy has been the fastest growing source of energy consumption in the World growing at a rate of 3% per annum (IEA, 2009) .According to Apergis and Payne (2012), the increased growth in renewable energy consumption has been due to environmental concerns about fossil energy consumption, volatility of oil prices and energy security concerns. The signing of the Kyoto Protocol and the establishment of carbon certificate traded markets like the European Union Emission Trading Scheme (EU ETS) has help increase the use of renewable energy. Since these emissions related Initiatives are confined to the developed world, the few studies on the relation between relation renewable energy consumption and economic growth have been restricted to the developed economies.

Apergis and Payne (2010) examine the relationship between renewable energy and economic growth in OECD countries from 1985 to 2005.They found that there is a bidirectional causal relationship relation between renewable energy and economic growth in both the short and the long run. Menyah and Rufael (2010) found a unidirectional relationship running from renewable energy consumption to economic growth in the USA from 1960 to 2007. The findings of Manyeh and Rufael supports that of Sadorsky (2010) who found that income cause the consumption of renewable energy in G7 countries in the long run.

Ozturk (2010 recommends that to obtain robust estimates for policy making, a multivariate system should be used in addition to inclusion of factors which are relevant to the economy under study. The TFP, non-renewable energy consumption, renewable energy and human capital have been some of the major contributors to both economic growth and energy consumption though some of them have not been given much attention in the literature.

3. Methodology

In this study, economic growth, productivity, energy prices and education on energy consumption (renewable and non-renewable) is examined. A Cobb-Douglas function in which energy consumption depends on economic growth productivity growth, and investment. Renewable energy consumption and non-renewable energy enter the model separately.

$$EC = f(\mathrm{Y}, TFP, EC, \mathrm{P}, L) \tag{1}$$

Equation is a production function with EC as energy consumption, economic growth (Y) v and total factor productivity (TFP), education (E), Price (P) and Population (L) as explanatory variables.

$$EC = e^{\varepsilon} Y^{\phi} TFP^{\rho} E^{\beta} P^{\alpha} L^{\theta} \tag{2}$$

Dividing equation (2) by population to obtain, equation (3) becomes:

$$\left(\frac{EC}{L}\right) = \left(\frac{Y}{L}\right)^{\phi} + \left(\frac{TFP}{L}\right)^{\rho} + \left(\frac{E}{L}\right)^{\beta} + \left(\frac{P}{L}\right)^{\alpha} + \varepsilon \tag{3}$$

Equation three can be written in growth terms by applying logs. Lower case variables denote logs. In addition, since the study is a panel study, equation (4) is written in a panel form by considering cross-sectional and time specific effects.

$$ec_{it} = \phi y_{it} + \rho \log tfp_{it} + \beta \log e_{it} + \alpha \log \mathrm{p}_{it} + \varepsilon_{it} \tag{4}$$

3.2 Data sources

Since energy prices are often subsidized in developing countries like Africa countries, it is difficult to get a uniform data on energy price or a consistent data overt time (Mahadevan and Asafu-Adjaye, 2006).Again; it is even difficult to get the subsidized prices since some of these countries do not keep proper records of energy prices. Following the work of Mahadevan and Asafu-Adjaye (2007) and Tang et al (2013), consumer price index is used as a proxy for energy prices. This is obtained from the World Development Indicators (WDI), 2013 edition. 11 oil producing Africa countries are used in this study. They are Algeria, Angola, Cameroon, Congo, Cote D'ivoire, Demographic Republic of Congo, Gabon, Ghana Nigeria, South Africa and Tunisia. Countries such as Chad, Cape Verde and Libya are omitted due to data unavailability. Annual data covering 1985 to 2011 are used. Annual data on education expenditure and GDP in current US dollars obtained from WDI, 2013 edition. TFP is hicks neutral and are obtained from the UNIDO productivity index. Renewable and non-renewable energy are in metric tonnes of oil equivalent. Renewable energy consumption is which is made up of biomass, hydro, waste, solar and wind grew at 0.4% annually in the countries under study from 1985 to 2011. In computing for non-renewable energy, renewable energy consumption is deducted total energy consumed over the estimated period. Figure 1 shows the historical trend of renewable and non-renewable energy of the selected countries from 1985 to 2011.

3.2 Estimation Procedure

The panel simultaneous equation captures a dynamic trend where one period lagged value of the dependent variable affect the current value. In order to cater for the problem of endogeneity, a set of instrumental variables are used in the generalized method of moments suggested by the Arellano and Bond (1991). Another advantage is that it avoids the correlation between the lag dependent variable and the error term as is in the case of OLS (Omri et al., 2014)

4.0 Discussion

There are two main forms of energy which are non-renewable energy and renewable energy. The non-renewable energy comprises of natural gas, gasoline, coal etc. whilst the renewable energy sources include solar, biomass, hydro, wind, geothermal, fuel wood etc. Table 1.0 reports the estimated results of the non-renewable energy consumption in selected oil producing countries in Africa.

Given environmental concerns and high fossil fuel prices, renewable energy is gradually becoming the fuel of choice due to the reason that it is considered carbon neutral. According to Sadorsky (2009), both emerging and developed economies are more concerned about global warming and energy security. This is because of high fossil fuel prices, volatile supply and the evidence that energy usage is a major cause of global warming. In the short run, demand for renewable energy is found to be price inelastic. Data available at IEA (2011) suggests that most of the renewable energy is consumed in the residential sector where a major part could be wood fuel or charcoal. In the short run, price changes leads to less than proportionate change in demand since there are no appropriate alternatives and there are also many suppliers with different prices.

Table 1. Estimated results

	Nigeria		Ghana		Algeria		South Africa	
	R	NR	R	NR	R	NR	R	NR
Productivity	0.003	-3.242		-4.136	1.341	0.866		0.587
Income	0.005	3.04	0.095	5.8	3.004	0.682	1.308	0.964
Price	-0.00012	-0.011	-0.0007	-0.014	-0.038	-0.002	-0.012	-0.003
Education	0.0002		-0.008		-0.664		0.068	

* where empty space denotes insignificant at 5% confidence level

The quantity demand of such forms of energy especially in the rural areas depends on the bargaining skills of the consumer. Algeria reported the highest short-run income elasticity at 3.004 whilst Nigeria reported the least at 0.005.The estimated results suggest that, in both Ghana and South Africa, productivity does not have any effect on the consumption of renewable energy in both the short and long run whereas productivity improvements increases renewable energy consumption in Nigeria and Algeria in the short run. The UEDT exhibits energy using behaviour in all countries except South Africa. This may be as a result of the continual availability and cheaper prices of renewable energy such as charcoal. For South Africa, it may be due to the abundant use of commercial forms of renewables such as solar panels. The effect of education on renewable energy consumption is varied among the countries. Whilst education has a positive relation with renewable energy consumption in Nigeria and South Africa, it has negative relation with consumption in Ghana and Algeria. This findings confirms that of Ackah et al (2014) on electricity in Ghana. This means that the higher people are educated in Ghana and Algeria, the less renewable energy they consume. Most educated people tend to use natural gas for cooking instead of charcoal especially in Ghana. Again, the educated usually move to the cities where traditional sources of renewable energy are not widely available. In South Africa, the consumption of renewable energy such as solar panels may be as a matter of prestige and class. Therefore, the educated tend to consume more to belong to the 'renewable class'.

4.3 Causality

Previous findings on the direction of causality between energy consumption and economic growth have been diverse as suggested by Ozturk (2010). In Africa, most of the energy consumption studies have concentrated on testing the direction of the energy-growth nexus. Soytas and Sari (2003) use cointegration test to examine the causality of energy and growth in South Africa and find that energy consumption causes growth without feedback. Esso (2010) finds a unidirectional causality from growth to energy in Ghana. Wolde-Rufael (2009) uses the Toda and Yamamoto to test for causality in a multivariate framework and reports a feedback relation between energy and growth for Ghana but a unidirectional causality from energy to growth in Algeria and South Africa. In the case of Nigeria, there is causality from growth to energy consumption without feedback. After testing for unit root and performing other necessary statistical test, the results of the causality test is reported in Table 2.0.

Table 2.0 Causality

Country	Method	Non-Renewable Energy		Renewable Energy	
		SR	LR	SR	LR
Nigeria	VAR	E to Y*	Feedback***	R to Y**	Feedback***
Ghana	VECM	Y to E**	E to Y**		R to Y**
Algeria	VAR	Feedback**	Feedback***	R to Y**	R to Y***
South Africa	VECM			R to Y**	

***, ** and * are 1%, 5% and 10% significance levels respectively. Feedback means bidirectional causality

In addition to renewable and non-renewable energy, the study included variables such as TFP, Human capital and prices in a multivariate function. The neutral hypothesis is confirmed in South Africa since there is no causal relation between non-renewable energy consumption and economic growth which may be as a result of the relative size of the budget allocated to energy. This supports the findings of Payne (2009).Payne (2009) uses the Toda-Yamamoto procedures to test for Granger causality with a production function framework for the US from 1949 to 2006 and finds no relation between renewable energy and growth. Apergis and Payne (2011) test the causality between renewable energy and growth for 20 OECD countries and find a feedback relation in the long-run which confirms the findings between renewable energy and growth in Nigeria. This finding is also supported by Sadorsky (2009) who finds evidence of bidirectional relation between renewable energy and growth for 18 emerging economies from 1994 to 2003.Similarly to the findings on renewable energy for Ghana, Bowden and Payne (2010) find a unidirectional causality from renewable energy to growth. The findings suggest that Nigeria, Ghana and Algeria should invest more in renewable energy since renewable energy consumption leads to growth in the long run.

5.0 Conclusion

The purpose of this study is to examine the impact income, price, education and productivity on renewable and non-renewable energy in selected oil producing Africa countries. Further, the study seeks to test for the causal direction between energy and growth in a multivariate function that includes variables such as TFP, education, and income. Depending on the order of integration, VECM and VAR models are used to test for the causal relation between energy and growth.

Education has an inverse relation with renewable energy consumption in Ghana and Algeria but a positive relation in Nigeria and South Africa. This result may reflect the kind of renewable energy consumed whether traditional or commercial. As consumers climb higher on the educational ladder, they tend to consume less of traditional sources of energy which is 'rural' and 'cheap such as firewood and consume commercial forms of renewable if available or natural gas.

The causality test suggests a long-run unidirectional causality from non-renewable energy to growth in Ghana and a bidirectional relation in Algeria and Nigeria. This indicates the importance of non-renewable energy forms to economic growth in these countries and therefore any form of non-renewable energy conservation without appropriate alternatives can hurt growth. The study finds no relation between non-renewable energy and growth in South Africa in the long –run. The test suggests a feedback relation between renewable and growth in Nigeria and a unidirectional causality from renewable to growth in Ghana and Algeria in the long-run. There is a short-run causality from renewable energy to growth in South Africa.

Both renewable and non-renewable energy affect growth in these countries. Again, productivity improvement enhances energy efficiency in these countries. The study suggests that in designing an effective energy policy, investment in productivity and renewable energy should be considered.

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Appendix A. Auxiliary residual test

Summary statistics	Nigeria		Algeria		Ghana	South Africa	
	E	R	E	R	E	E	R
Auxiliary Residual							
Irregular							
Normality	1.413	0.451	0.153	0.968	1.438	1.617	0.542
Skewness	0.449	0.09	0.085	0.257	0.795	1.612	0.21
Kutosis	0.964	0.061	0.068	0.711	0.643	0.004	0.332
Slope							
Normality	0.771	1.551	0.029	0.591			2.522
Skewness	0.723	0.55	0.002	0.048			1.013
Kurtosis	0.049	1.001	0.026	0.542			1.509
Level							
Normailty	0.637	0.337	0.104	1.625	0.535	1.324	13.59
Skewness	0.276	0.338	0.011	0.303	0.51	0.011	6.798
Kurtosis	0.361	0.038	0.095	1.322	0.025	1.121	6.792