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Short- and Long-Run Analysis of Factors Affecting Electricity Consumption in Sub-Saharan Africa

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ABSTRACT

This paper explores the causal relationship between electricity consumption, gross domestic product (GDP), trade openness, financial development, and industry using a vector error correction model for five sub-Saharan countries. Results indicate that in the long run, all series exert an influence on electricity consumption in Cote d'ivioire and Zambia. Short run estimates reveal causality running from financial development and GDP to electricity consumption in Cote d'ivioire and South Africa. A modified version of Granger causality developed by Toda and Yamamoto (1995) found no causality in electric power consumption for Kenya. Since these countries differ economically, politically, and geographically, no universal policy implication can be surmised.

Keywords: Electricity Consumption, Vector Error Correction Model, Sub-Saharan Africa
JEL Classifications: C32, O13, O47, O55, Q43, Q48

1. INTRODUCTION

Electricity is a vital contributor to the economy. It stimulates improvements in many aspects of society including: employment, health, food preservation, farming, medical technology, and education (Emodi and Boo, 2015; Tucker et al., 2014). As electricity consumption continues to grow, so do nations. A country's economy and electricity use are linked (US Energy Information Administration, 2013). The World Bank reported that in 2012, 621 million people lacked access to electricity in Sub-Saharan Africa (World Bank, 2013). Governments have recognized that electric power supply is a pre-requisite for social prosperity and consequently gained momentum in making power available to citizens (Turkson and Wohlgemuth, 2001; Squalli, 2007; Poloamina and Umoh, 2013). Other initiatives, such as power Africa have been established to provide electricity in Sub-Saharan Africa (The White House, 2013). A widely studied driver of electricity consumption is gross domestic product (GDP) which has attracted considerable research work. Starting with the work of Kraft and Kraft (1978), authors have employed causality tests to investigate the relationship between electricity consumption and income. Others have extended the bivariate models to include macroeconomic variables such as energy prices, employment, and capital (Masih and Masih, 1996; Narayan and Singh, 2007; Odhiambo, 2009). Results of these causality tests shed light on future electricity policies.

This study seeks to analyze causality between electric power consumption, GDP, trade openness, financial development, and industry in five sub-Saharan countries. The motivation of this paper stems from the fact that there are few published studies that research causality between electricity consumption and macroeconomic variables in sub-Saharan Africa.

Furthermore, existing studies use cross-sectional data which does not address country-specific issues whereas this study looks at causality in individual countries. The countries used in this study are spatially dispersed which give an indication of what is happening around the continent. The inclusion of variables such as industry, trade openness, and financial development will fill the gaps in previous studies which looked at bivariate networks that may suffer from omission variable bias. The variables are introduced to further understand the issues affecting electricity consumption in sub-Saharan economies. Finally, this study will provide an analysis at a time when governments are coming up with initiatives to generate more electricity to their citizens. Initiatives such as vision 2030 for Kenya and Power Africa seek to double the population in sub-Saharan Africa with access to electricity have been recently implemented and results from this study can provide an insight on the electricity industry in these countries (The White House, 2013).

The rest of the paper is organized as follows: section 2 describes the data and the econometric methodology Section 3 presents the results and discussion Section 4 concludes this paper with some policy implications.

2. LITERATURE REVIEW

The electric power consumption and economic growth nexus in Africa has been a subject of considerable academic scrutiny over the past few decades. A study by Wolde-Rufael (2006) of 17 African countries found that past values of economic growth had a predictive ability in determining present values of electricity consumption in some countries; while for other countries; past values of electricity consumption had a predictive ability in determining the present values of economic growth. Other results showed feedback relationships while some indicated that there was no causal relationship (Wolde-Rufael, 2006).

Akinlo (2009) studied the causal relationship between electricity consumption and economic growth in Nigeria. Using a bivariate error correction method and the Hodrick-Prescott filter to decompose the trend and cyclical components of the data, Akinlo discovered unidirectional causality in Nigeria running from electricity consumption to GDP. Yuan et al. (2007) used the same method and found unidirectional causality running from electricity consumption to real GDP in China. Jumbe (2004) decomposed GDP into agricultural and non-agricultural GDP for Malawi when investigating causality between economic growth and electricity consumption using Granger causality and the error correction method. Odhiambo (2009) employed a trivariate model to study the causal relationship between electricity consumption, economic growth, and employment. Results revealed bidirectional causality between electricity consumption and economic growth, both in the long run and short run. Ozturk and Biglili (2015) took a different approach and studied the relationship between biomass energy consumption and GDP for 51 African countries between 1980 and 2009. They found that increasing biomass consumption by 1% would increase GDP by 1.8%. Biomass energy represents 80% of total energy consumption in these regions and plays a role in GDP.

In other parts of the world, Ghosh (2002) found unidirectional causality running from electricity consumption per capita to GDP per capita for India while in Turkey, there was strong evidence of unidirectional causality running from electricity consumption to income between 1950 and 2000 (Altinay and Karagol, 2005). Similar findings were found in China (Shiu and Lam, 2004). Unidirectional causality running from electricity consumption to GDP was also found in seven South American countries (Yoo and Kwak, 2010). These studies employed bivariate models to conduct their analysis which do not capture other drivers of energy use in the economy. It is from this backdrop that this paper seeks to investigate the electric power consumption GDP nexus by including financial development, trade openness and industry. Widely accepted time-series techniques will be employed for the period 1971-2011.

3. DATA AND ESTIMATION TECHNIQUES

3.1. Data

The countries studied in this paper are Cote d'Ivioire, Congo Republic, Kenya, South Africa and Zambia. Regions were selected based on data availability and the spatial nature around the continent. They represented the four regions in sub-Saharan Africa with Cote d'ivioire on the West, Congo Republic representing the central region, Kenya representing the east while South Africa and Zambia represent the southern region. Table 1 presents several regional statistics. The population in our selected countries ranges from 4.45 million to 52.98 million in 2013. The average age of each country is 54 years except for South Africa. South Africa, which is the highest coal-producing country in Africa produced 259.6 billion kWh in 2013.

The choice of variables is motivated by the fact that demand for electricity is affected by economic growth, industrial activity, trade, and financial development; all which have increased the economic activity in sub-Saharan Africa. Annual GDP growth has increased at an average of 5.5% between 1971 and 2011 for the six countries. This implies that the increasing number of factories and shopping centers *inter alia* puts pressure on energy demand. Therefore, the GDP and industry variables are included to capture their roles in electricity consumption. Financial development also has a direct link to energy use. Well-developed financial markets boost domestic investment which brings superior technology and know-how, thus reducing energy use and consequently the cost of production for firms. On the other hand, developed financial markets promote economic activity and boosts energy use. This variable is included to examine its effect on electric power consumption. According to Islam et al. (2013), the proxy used

Table 1: Regional statistics for Cote d'Ivioire, Congo Republic, Kenya, South Africa and Zambia (2013)

Description	Cote d'ivioire	Congo republic	Kenya	South Africa	Zambia
Year of formation	1960	1960	1963	1994[1]	1964
Population (millions)	20.40	4.45	44.35	52.98	14.54
GDP (current US$) in billions	31.10	14.09	55.24	350.63	26.82
GDP growth (2012-2013) %	9	3	6	2	7
Electricity production in billions (kWh)	6.10	1.23	7.85	259.60	11.45

GDP: Gross domestic product, [1]The Union of South Africa, a dominion within the British Commonwealth that was ruled by the country's white minority, was formed in 1910. Black majority rule was achieved in a new, nonracial government in 1994 for financial development is domestic credit[2] issued to private sectors as shares of GDP. Countries experiencing increased trade liberalization witness an increase in energy use by the industrial and transport sector. Trade liberalization is expected to increase energy use for countries with low per capita incomes and reduce energy use for those with high per capita incomes (Cole, 2006). Trade openness is defined as the ratio of external trade (imports plus exports) to GDP, as used in the literature. The data was obtained from World Development Indicators, 2015, and published by the World Bank (World Bank, 2015).

Causality among these variables can run either way; GDP can be modeled as a function of electric power consumption and the other variables. Similarly, trade openness, financial development, and industry can be modeled against one another. Thus, the vector error correction model (VECM) is applied for this analysis.

3.2. Model Specification

A linear combination of two or more non-stationary series with the same order of integration may be stationary. If such a stationary linear combination exists, the series are considered to be cointegrated and long-run equilibrium relationships exists between the two (Engle and Granger, 1987). The most commonly used method to test for cointegration is the Johansen cointegration test based on the autoregressive representation discussed by Johansen (1988) and Johansen and Juselius (1990). This test determines the number of cointegrating equations by providing two different likelihood ratio (LR) tests. The first is based on the trace statistic while the other on maximum eigenvalue. Although cointegration implies that causality exists between the two series, it does not indicate the direction of the causal relationship. Thus, the VECM is used to determine the direction of causality. The VECM is attractive in the sense that it can help capture the long- and short-term dynamics among variables that Granger causality tests cannot detect. The dynamic Granger causality can be captured from the VECM derived from the long-run cointegrating relationship (Engle and Granger, 1987). The VECM of the following form is employed.

$$\Delta elec_t = \alpha_1 + \sum_{i=1}^{l}\beta_{1i}\Delta elec_{t-i} + \sum_{i=1}^{m}\gamma_{1i}\Delta fd_{t-i} + \sum_{i=1}^{n}\alpha_{1i}\Delta gdp_{t-i} + \sum_{i=1}^{o}\delta_{1i}\Delta ind_{t-i} + \sum_{i=1}^{p}\mu_{1i}\Delta trade_{t-i} + \xi_{1i}ECT_{t-1} + u_{1t} \quad (1)$$

$$\Delta fd_t = \alpha_2 + \sum_{i=1}^{l}\beta_{2i}\Delta elec_{t-i} + \sum_{i=1}^{m}\gamma_{2i}\Delta fd_{t-i} + \sum_{i=1}^{n}\alpha_{2i}\Delta gdp_{t-i} + \sum_{i=1}^{o}\delta_{2i}\Delta ind_{t-i} + \sum_{i=1}^{p}\mu_{2i}\Delta trade_{t-i} + \xi_{2i}ECT_{t-1} + u_{2t} \quad (2)$$

$$\Delta gdp_t = \alpha_3 + \sum_{i=1}^{l}\beta_{3i}\Delta elec_{t-i} + \sum_{i=1}^{m}\gamma_{3i}\Delta fd_{t-i} + \sum_{i=1}^{n}\alpha_{3i}\Delta gdp_{t-i} + \sum_{i=1}^{o}\delta_{3i}\Delta ind_{t-i} + \sum_{i=1}^{p}\mu_{3i}\Delta trade_{t-i} + \xi_{3i}ECT_{t-1} + u_{3t} \quad (3)$$

$$\Delta ind_t = \alpha_4 + \sum_{i=1}^{l}\beta_{4i}\Delta elec_{t-i} + \sum_{i=1}^{m}\gamma_{4i}\Delta fd_{t-i} + \sum_{i=1}^{n}\alpha_{4i}\Delta gdp_{t-i} + \sum_{i=1}^{o}\delta_{4i}\Delta ind_{t-i} + \sum_{i=1}^{p}\mu_{4i}\Delta trade_{t-i} + \xi_{4i}ECT_{t-1} + u_{4t} \quad (4)$$

$$\Delta trade_t = \alpha_5 + \sum_{i=1}^{l}\beta_{5i}\Delta elec_{t-i} + \sum_{i=1}^{m}\gamma_{5i}\Delta fd_{t-i} + \sum_{i=1}^{n}\alpha_{5i}\Delta gdp_{t-i} + \sum_{i=1}^{o}\delta_{5i}\Delta ind_{t-i} + \sum_{i=1}^{p}\mu_{5i}\Delta trade_{t-i} + \xi_{5i}ECT_{t-1} + u_{5t} \quad (5)$$

Where:

elec=Electricity Electric power consumption (kWh)

fd=Financial development Domestic credit to private sector (percenatage of GDP)

gdp=GDP GDP (constant 2005 US$)

ind=Industry Industry, value added (percentage of GDP)

trade=Trade openness Exports of goods and services (constant 2005 US$), Imports of goods and services (constant 2005 US$)

Δ is the difference operator, error correction term (ECT) refers to the ECT derived from the long run-cointegrating relationship via the Johanssen maximum likelihood procedure, and $\mu_{i,t}$'s (for *i*=1,2,3.) are serially uncorrelated random error terms with mean zero. Equation (1) will be used to test causation from GDP, trade openness, financial development and industry to electricity consumption, and equation (2) will be used to test causality from electricity consumption, GDP, trade openness and industry to financial development and so on.

A consequence of relationships described by equations (1-5) is that either $\Delta elect_t$, Δfd_t, Δgdp_t, Δind_t, $\Delta trade_t$ or a combination of them must be caused by ECT_{t-1} which itself is a function of $elec_{t-1}$, fd_{t-1}, gdp_{t-1}, ind_{t-1}, $trade_{t-1}$. Intuitively, if [$elec_t$, fd_t, gdp_t, ind_t, $trade_t$] share a common trend, then the current change in $elec_t$ (say the dependent variable) is partly the result of $elec_t$ moving into alignment with the trend value of fd_t, gdp_t, ind_t, $trade_t$ (the independent variable). The ECM opens up an additional channel for Granger causality, through the ECT.

Granger Causality can be exposed through the statistical significance of: (i) the lagged ECTs (ξ_s) by a t-test or (ii) a joint test applied to the significance of the sum of the lags of each explanatory variables $(\beta's, \gamma's, \alpha's, \delta's, \mu's)$ in turn by a joint *F* or Wald χ^2 test; or (iii) a joint test of all the set of terms described in (i) and (ii), by a joint a joint *F* or Wald χ^2 test, i.e. taking each of the parenthesized terms separately; $(\gamma's, \alpha's, \delta's, \mu's, \xi's)$ in equation (1), the $(\beta's, \alpha's, \delta's, \mu's, \xi's)$ in equation (2) and so

2 Domestic credit includes gross credit to various sectors, excluding credit to the central government which is net. The banking sector consists of monetary authorities, banking institutions and institutions which do not accept transferable deposits but incur liabilities such as, time and savings deposits Islam, F., et al. (2013). "Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis." Economic Modelling 30(0): 435-441.

on. The non-significance of both the t and F or Wald χ^2 test in the VECM indicates econometric exogeneity for the dependent variables (Masih and Masih, 1996).

The VECM indicates the direction of causality among variables and allows us to distinguish between "short-run" and "long-run" Granger causality. When the variables are cointegrated, then in the short run, deviations from this long-run equilibrium will feed back on the changes in the dependent variable in order to force the movement towards the long-run equilibrium. If the dependent variable (e.g. change in electricity consumption) is driven by this long-run equilibrium error, then it is responding to this feedback. If not, it is responding only to short-term shocks to the stochastic environment. The F-tests of the differenced explanatory variables give us an indication of the "short term" causal effects, whereas the "long run" causal relationship is implied through the significance or t-test (s) of the lagged error-correction term, which contains long term information since it is derived from the long-run cointegrating relationships. The long-run causality can be tested by looking at the significance of the speed of adjustment "ξ," which is the coefficient of the error-correction term. The significance of "ξ," indicates that the long-run equilibrium relationship is directly driving the dependent variable.

The ECM includes the ECT and lagged first differences of the endogenous variables. The ECT indicates the extent of variation from the long-run equilibrium which was present in the previous period. The coefficient attached to the ECT fulfills the role of the adjustment parameter, which shows the proportion of the disequilibrium that is covered during the subsequent period. The coefficients attached to the lagged first differences provide an indication of the short run relationship between the endogenous variables (Enders, 2004).

4. EMPIRICAL RESULTS

4.1. Tests for Unit Root

Tests for unit roots were conducted using the augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwaitkowski-Phillips-Schmidt-Shin (KPSS) tests (Dickey and Fuller, 1981; Phillips and Perron, 1988). The KPSS test is used to complement the widely used ADF and PP tests in order to ensure robust results. The results of the unit root tests are reported in Table 2. Results indicate that all the series were $I(1)$.

4.2. Tests for Cointegration

Since the variables share common integrational properties, we test whether there is a long-run cointegrating relationship between the series. Test results for cointegration via the Johansen and Juselius maximum likelihood procedure are given in Table 3.

The Table 3 presents the trace statistics used to select the maximum number of cointegrating equations. We follow Toda (1994) and Lüutkepohl et al. (2001) and use the trace statistics to select the number of cointegrating equations. The optimal lag length was selected using the sequential modified LR test statistic (LR), the Akaike information criteria, the Schwarz information criterion, the final prediction error and the Hannan-Quinn information criterion.

Table 2: Unit root test results

	Electricity consumption			Financial development			GDP			Industry			Trade openness		
	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS
Variables in levels															
Congo Republic	0.60	−1.87	0.15**	−1.65	−1.82	0.14*	−2.37	−2.04	0.14*	−2.54	−2.54	0.08	−2.41	−2.46	0.13*
Cote d' Ivoire	−3.02	−3.02	0.14**	−2.20	−2.30	0.12*	−2.59	−2.68	0.08	−2.97	−3.00	0.10	−2.75	−2.75	0.14*
Kenya	−2.43	−2.43	0.17**	−2.52	−2.41	0.16**	−1.82	−3.59**	0.16**	−2.99	−2.99	0.14*	−2.67	−2.70	0.18**
South Africa	−1.72	−1.79	0.20**	−2.26	−1.99	0.12	−1.56	−0.89	0.14*	−3.07	−3.07	0.13*	−2.16	−2.30	0.16**
Zambia	−2.65	−2.80	0.10	−1.85	−1.69	0.15**	0.82	1.23	0.18**	−4.90***	−1.53	0.08	−1.31	−1.39	0.19**
Variables in first differences															
Congo Republic	−8.57***	−8.57***	0.10	−5.25***	−5.24***	0.12*	−3.57**	−3.64**	0.10	−6.27***	−6.37***	0.10	−5.57***	−5.53***	0.07
Cote d' Ivoire	−6.85***	−6.84***	0.10	−4.95***	−4.99***	0.19**	−3.65**	−3.93**	0.08	−6.69***	−6.69***	0.07	−7.42***	−8.48***	0.14*
Kenya	−6.26***	−6.26***	0.12	−7.79***	−7.75***	0.15**	−5.45***	−5.45***	0.13*	−7.38***	−8.89***	0.10	−7.81***	−7.81***	0.12
South Africa	−5.45***	−5.41***	0.07	−1.40	−5.71***	0.15**	−4.34***	−4.15**	0.12*	−4.59***	-4.53***	0.20**	−4.98***	−4.92***	0.16**
Zambia	−4.96***	−4.91***	0.14*	−4.78***	−4.36***	0.11	−7.14***	−7.15***	0.22**	−5.29***	−5.27***	0.11	−5.63***	−5.85***	0.10
							With constant and trend								
							1%	5%	10%						
						ADF and PPP	−4.205	−3.527	−3.195						
						KPSS	0.216	0.146	0.119						

ADF: Augmented Dickey–Fuller unit root tests, PP: Phillips-Perron unit root tests, KPSS: Kwiatkowski–Phillips–Schmidt–Shin. ***Means significant at the 1% level, **Means significant at the 5% level and *Means significant at the 10% level. All variables are in logs. In all the cases, the unit root tests have been applied using both the model with constant and the model with constant and a linear trend, and the results are the same. The values in the cells correspond to the statistic obtained with the model with constant and a linear trend, GDP: Gross domestic product

Table 3: Johansen and juselius cointegration tests (variables: electricity consumption, GDP, industry, financial development and trade openness)

Variables: Electricity consumption, GDP, industry, financial development and trade openness					
Country	***r*=0**	***r*≤1**	***r*≤2**	***r*≤3**	***r*≤4**
Congo republic					
Trace statistic	121.06***	77.43***	51.70**	30.34**	14.41*
Critical values (0.05)	95.75	69.82	47.86	29.80	15.49
Cote d' ivioire					
Trace statistic	76.80***	47.11*	26.28	11.96	2.23
Critical values (0.05)	69.82	47.86	29.80	15.49	3.84
Kenya					
Trace statistic	106.91***	45.35**	20.84	9.32	1.46
Critical values (0.05)	69.82	47.86	29.80	15.49	3.84
South Africa					
Trace statistic	80.80***	47.23*	24.45	7.96	0.00
Critical values (0.05)	69.82	47.86	29.80	15.49	3.84
Zambia					
Trace statistic	79.68***	46.60*	25.17	8.80	0.53
Critical values (0.05)	69.82	47.86	29.80	15.49	3.84

r: Number of cointegrating vectors. *.** and *** rejection of the null hypothesis at the 10%, 5% and 1% levels of significance, respectively. In column 3 (*r*=0) we test the null hypothesis of no cointegration against the alternative of cointegration, GDP: Gross domestic product

Table 4: VECM results

Null hypothesis	Short run causality (Wald test - Chi-square values of joint lags from VECM estimation)
Congo Republic	
ECT (t-statistics in brackets)	−0.5606 [−2.8883]
ΔGDP→Δelec_cons	0.9767
Δtrade_openness→Δelec_cons	0.1056
Δindustry→Δelec_cons	0.6768
Δfinancial development→Δelec_cons	0.7996
Cote d'Ivioire	
ECT (t-statistics in brackets)	−0.4312 [−2.1730]
ΔGDP→Δelec_cons	0.0754*
Δtrade_openness→Δelec_cons	0.0039***
Δindustry→Δelec_cons	0.639
Δfinancial development→Δelec_cons	0.213
Kenya	
ECT	−0.105 [−1.5086]
ΔGDP→Δelec_cons	0.7926
Δtrade_openness→Δelec_cons	0.4046
Δindustry→Δelec_cons	0.6155
Δfinancial development→Δelec_cons	0.8930
South Africa	
ECT	0.0045 [0.0626]
ΔGDP→Δelec_cons	0.0186**
Δtrade_openness→Δelec_cons	0.2693
Δindustry→Δelec_cons	0.1557
Δfinancial development→Δelec_cons	0.8693
Zambia	
ECT	0.0169 [−2.5199]
ΔGDP→Δelec_cons	0.2167
Δtrade_openness→Δelec_cons	0.0495**
Δindustry→Δelec_cons	0.5165
Δfinancial development→Δelec_cons	0.1833

We only report results for causality running from variables to electricity consumption. t-statistics in square brackets; → means variable x does not Granger cause variable y;***Means significant at the 1% level, ** Means significant at the 5% level and *Means significant at the 10% level, VECM: Vector error correction model, GDP: Gross domestic product, ECT: Error correction term

4.3. VECM Results

Next, the VECM was ran with results presented in Table 4.

In Congo, there is a long run causality running from trade openness to electricity consumption. Results indicate that approximately 56% of long run disequilibrium is corrected each month by changes in the ln_elec_cons equation. A value of −0.56 for the coefficient of the error term suggests that ln_elec_cons will converge towards its long-run equilibrium at a moderately fast speed. We do not see any significant effects from our short-run parameters to electricity consumption. Results for Cote d'Ivioire indicate that there is a long-run causality running from GDP, trade openness, financial development, and industry to electricity consumption. Results also suggest that about 43% of long run disequilibrium is corrected each year by changes in the ln_elec_cons equation. This implies that the ln_elec_cons will converge towards its long-run equilibrium level at a moderate speed. In the short-run, electricity consumption is affected by financial development and GDP.

In South Africa, the short-term parameters suggest causality running from financial development to electric power consumption and from GDP to electric power consumption. Results for Zambia indicate that there is a long-run causality from GDP, trade openness, financial development, and industry to electricity consumption. A value of 0.1 for the coefficient of the error term indicates that ln_elec_cons will converge towards its long-run equilibrium at a slow speed. In the short-run, we see Granger causality running from GDP to electricity consumption.

We do not see any significant effects from our long- or short-run parameters for Kenya meaning that there could be parameters outside the model that affect electricity consumption. These are findings similar to those found by Dogan (2014). To investigate this further, the trade openness series was decomposed to imports and exports. We also include a variable to measure growth in urban population. Table 5 illustrates the growth in series across countries between 1971 and 2011.

A causal analysis of the data in Table 5 indicates that Kenya experienced the largest growth in urban population and financial development since 1971. Nairobi, Kenya's capital, consumes close to 56.2% of the total power in the country. Although the capital has 835,202 customers, reports indicate that street lighting is the major consumer of power. Major industries have set up their own power plants to substitute Kenya's power which is sometimes unreliable (Ngigi, 2013).

We then proceed to use a modified version of Granger causality developed by Toda and Yamamoto (1995) to investigate the causal effect of exports, imports, GDP, industry, urban population, and financial development on electricity consumption in Kenya. The procedure proposed by Toda and Yamamoto ensures that the usual test statistics for Granger causality have standard asymptotic distributions. The basic idea of the approach is to artificially augment the correct order k, by the maximal order of integration, d_{max} (Pittis, 1999). A $(k + d_{max})^{th}$ order of vector autoregression is estimated and the coefficients of the last lagged d_{max} vectors are ignored. To use this approach, the true lag length (k) and the maximum order of integration (d_{max}) of the series need to be obtained. The advantage of using the Toda and Yamamoto (1995) method is that it does not require a priori knowledge of cointegration within the system (Zapata and Rambaldi, 1997). Using the Toda and Yamamoto (1995) approach, the Granger causality tests were conducted using five lags (k=4 and d_{max}=1). The unit root tests are presented in table 6 and results for the Granger Causality tests presented in Table 7.

Results indicate no causality running between growth in electricity consumption and other variables. This confirms the notion that in Kenya, there are factors outside of our system which Granger cause electricity consumption.

5. CONCLUDING REMARKS

This paper has investigated the causal relationship between electric power consumption, GDP, trade openness, financial development, and industry using a VECM for five sub-Saharan countries over the period 1971-2011. The ADF and Johansen maximum likelihood tests were used to examine for unit roots and cointegration prior to testing for causality. Results indicate that there is a long-run causality running from GDP, trade openness, financial development, and industry to electricity consumption in Cote D' Ivioire and Zambia. We also see long-run causality running from trade openness to electricity consumption in Congo. Results reveal short-run causality running from financial development and GDP to electricity consumption in Cote D' Ivioire and South Africa. In Zambia, short-run results report causality running from GDP to electricity consumption. We did not find any long-or short-run causality effects on electricity consumption in Kenya.

Table 5: Average growth rates by Country from 1971 to 2011

Variables	Congo Republic %	Cote d'Ivioire %	Kenya %	South Africa %	Zambia %
Electricity consumption	7.28	5.72	5.11	4.01	1.67
Exports	5.28	4.77	3.79	2.50	4.41
Imports	8.16	4.38	4.85	3.63	4.67
GPD	4.30	2.76	4.13	2.57	2.41
Industry	4.27	0.78	−0.26	−0.46	−0.39
Urban	4.05	4.78	5.35	2.77	3.55
Financial development	1.12	−0.42	2.34	1.53	2.05

GDP: Gross domestic product

Table 6: Unit root test results – Kenya

Variables	Series	ADF		PP		KPSS	
		C	CT	C	CT	ETA (mu)	ETA (tau)
Growth in electricity consumption	elec_growth	−6.1443***	−6.4148***	−6.1701***	−6.4215***	0.3346	0.1228*
Growth in exports	exports_growth	−7.2350***	−7.2789***	−7.2243***	−7.2993***	0.2078	0.0605
Growth in imports	imports_growth	−6.1814***	−6.4164***	−6.1836***	−6.5625***	0.3609*	0.0807
Growth in GDP	gdp_growth	−6.0797***	−5.7656***	−6.0797***	−5.7656***	0.4337*	0.1313*
Growth in industry	industry_growth	−7.6949***	−7.5989***	−9.2350***	−9.2287***	0.1169	0.1085
Growth in urban population	urban_growth	−2.0815	−1.3427	−2.0904	−1.4451	0.4749**	0.1574**
	Δurban_growth	−5.0831***	−5.3510***	−5.0872***	−5.2707***	0.2951	0.0512
Growth in financial development	fd_growth	−7.8909	−7.9271	−7.8450	−7.9271	0.2175	0.1782**

	Without trend			With constant and trend		
	1%	5%	10%	1%	5%	10%
ADF and PP	−3.605	−2.937	−2.607	−4.205	−3.527	−3.195
KPSS	0.739	0.463	0.347	0.216	0.146	0.119

ADF: Augmented Dickey-Fuller unit root tests, PP: Phillips-Perron unit root tests, KPSS: Kwiatkowski–Phillips–Schmidt–Shin. ***Means significant at the 1% level, **means significant at the 5% level and *means significant at the 10% level. In all the cases, the unit root tests have been applied using both the model with constant (C) and the model with constant and a linear trend (CT)

Table 7: VAR Granger causality tests

Null hypothesis	Observations	*F*-statistic	*P*
exports_growth does not Granger cause elec_growth	36	0.4735	0.7924
elec_growth does not Granger cause exports_growth		1.5076	0.2232
imports_growth does not Granger cause elec_growth	36	1.5801	0.2021
elec_growth does not Granger cause imports_growth		0.8965	0.4986
gdp_growth does not Granger cause elec_growth	36	0.4590	0.8028
elec_growth does not Granger cause gdp_growth		1.5474	0.2113
industry_growth does not Granger cause elec_growth	36	1.5921	0.1988
elec_growth does not Granger cause industry_growth		0.4644	0.7990
urban_growth does not Granger cause elec_growth	36	0.2090	0.9556
elec_growth does not Granger cause urban_growth		0.2780	0.9208
fd_growth does not Granger cause elec_growth	36	0.7538	0.5913
elec_growth does not Granger cause fd_growth		0.9112	0.4897

VAR: Vector autoregression

This prompted further investigation of the factors driving electricity consumption in Kenya. The GDP series was decomposed into imports and exports. The inclusion of an urbanization variable was also introduced along with industry and financial development. Then, a modified version of Granger causality developed by Toda and Yamamoto (1995) was used to investigate the causal effect of growth in exports, imports, GDP, industry, urban population, and financial development on electricity consumption in Kenya. We found no causality from the variables for growth in electricity consumption. This suggests that there are forces outside our model which Granger cause electricity consumption.

An understanding of long and short run causality among the series and their direction, if any, is more than a matter of just intellectual curiosity - they have significant policy implications for balancing economic growth *vis-à-vis* electric power consumption for sub-Saharan countries. Nonetheless, because these countries do not necessarily share similar political and economic traits, no single universal policy implication can be inferred from the results. It is however important to note that GDP and financial development play an important role in predicting future values of electricity consumption in Cote d' ivioire, Zambia, and South Africa. The regions have witnessed an average growth in GDP of 2.6% over the last 40 years. The GDP and financial development interdependence will lead to higher energy consumption and emerging economies that continue to develop financial markets should see an increase in energy demand. Any energy demand projections in these economies that exclude financial development might provide inaccurate estimate of energy demand.

The VECM and Granger causality tests yield consistent results but interpretations ought to be treated with caution due to the possible loss in power associated with the small sample size. Moreover, the variables selected may not be sophisticated enough to yield robust policy recommendations. The significant role played by non-grid electric power consumption from small and medium sized industries are not taken into consideration here. Frequent power losses have been offset by power generators which would raise data concerns due to non-inclusion in official statistics. These missing statistics may have affected our results for Kenya.

REFERENCES

Akinlo, A.E. (2009), Electricity consumption and economic growth in Nigeria: evidence from cointegration and co-feature analysis. Journal of Policy Modeling, 31(5), 681-693.

Altinay, G., Karagol, E. (2005), Electricity consumption and economic growth: evidence from Turkey. Energy Economics, 27(6), 849-856.

Cole, M.A. (2006), Does trade liberalization increase national energy use? Economics Letters, 92(1), 108-112.

Dickey, D.A., Fuller, W.A. (1981), Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica, 49(4), 1057-1072.

Dogan, E. (2014), Energy consumption and economic growth: evidence from low-income countries in sub-saharan Africa. International Journal of Energy Economics and Policy, 4(2), 154-162.

Emodi, N.V., Boo, K. (2015), Sustainable energy development in Nigeria: overcoming energy poverty. International Journal of Energy Economics and Policy, 5(2), 580-597.

Enders, W. (2004), Multiequation time-series models. Applied Econometric Time Series. New York: John Wiley & Sons.

Engle, R.F., Granger, C.W.J. (1987), Co-integration and error correction: representation, estimation, and testing. Econometrica, 55(2), 251-276.

Ghosh, S. (2002), Electricity consumption and economic growth in India. Energy Policy, 30(2), 125-129.

Islam, F., Muhammad, S., Ashraf, U.A., Mahmudul, A.M. (2013), Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis. Economic Modelling, 30(0), 435-441.

Johansen, S. (1988), Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control, 12(2-3), 231-254.

Johansen, S., Juselius, K. (1990), Maximum likelihood estimation and inference on cointegration-With applications to the demand for money. Oxford Bulletin of Economics and Statistics, 52(2), 169-210.

Jumbe, C.B.L. (2004), Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi. Energy Economics, 26(1), 61-68.

Kraft, J., Kraft, A. (1978), On the relationship between energy and GNP. The Journal of Energy and Development, 3(2), 401-403.

Lüutkepohl, H., Saikkonen, P., Trenkler, C. (2001), Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process. Econometrics Journal, 4(2), 287-310.

Masih, A.M.M., Masih, R. (1996), Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modelling techniques. Energy Economics, 18(3), 165-183.

Narayan, P., Singh, B. (2007), The electricity consumption and GDP nexus for the Fiji Islands. Energy Economics, 29(6), 1141-1150.

Ngigi, G. (2013), Nairobi Consumes Half of Kenya Power's Energy Supply. The Business Daily, Nation Media Group.

Odhiambo, N.M. (2009), Electricity consumption and economic growth in South Africa: a trivariate causality test. Energy Economics, 31(5), 635-640.

Ozturk, I., Bilgili, F. (2015), Economic growth and biomass consumption nexus: dynamic panel analysis for Sub-Sahara African countries. Applied Energy, 137(0), 110-116.

Phillips, P.C.B., Perron, P. (1988), Testing for a unit root in time series regression. Biometrika, 75(2), 335-346.

Pittis, N. (1999), Efficient estimation of cointegrating vectors and testing for causality in vector autoregressions. Journal of Economic Surveys, 13(1), 1-35.

Poloamina, I.D., Umoh, U.C. (2013), The determinants of electricity access in Sub-Saharan Africa. The Empirical Econometrics and Quantitative Economics Letters, 2(4), 65-74.

Shiu, A., Lam, P.L. (2004), Electricity consumption and economic growth in China. Energy Policy, 32(1), 47-54.

Squalli, J. (2007), Electricity consumption and economic growth: bounds and causality analyses of OPEC members. Energy Economics, 29(6), 1192-1205.

The White House. (2013), White House fact sheet: powering Africa: increasing access to power in sub-saharan Africa. Available from: http://www.whitehouse.gov/the-press-office/2014/08/05/fact-sheet-powering-africa-increasing-access-power-sub-saharan-africa. [Last retrieved on 2015 Jan].

Toda, H.Y. (1994), Finite sample properties of likelihood ratio tests for cointegrating ranks when linear trends are present. The Review of Economics and Statistics, 76(1), 66-79.

Toda, H. Y. and T. Yamamoto (1995). "Statistical inference in vector autoregressions with possibly integrated processes." Journal of Econometrics 66(1-2): 225-250.

Tucker, R., Schloss, Z., Leitman, M., Olivier, D. (2014), Affordable Electricity and Economic Development: the Role of Electric

Cooperatives in the 21st Century, National Rural Electric Cooperative Association.

Turkson, J., Wohlgemuth, N. (2001), Power sector reform and distributed generation in sub-Saharan Africa. Energy Policy, 29(2), 135-145.

US Energy Information Administration. (2013), Annual Energy Outlook 2013. Washington, DC: US Energy Information Administration.

Wolde-Rufael, Y. (2006), Electricity consumption and economic growth: a time series experience for 17 African countries. Energy Policy, 34(10), 1106-1114.

World Bank. (2013), World Energy Outlook 2014. Washington, D.C: The World Bank.

World Bank. (2015), World Development Indicators. Washington, D.C: World Bank Group.

Yoo, S.H., Kwak, S.Y. (2010), Electricity consumption and economic growth in seven South American countries. Energy Policy, 38(1), 181-188.

Yuan, J., Changhong, Z., Shunkun, Y., Zhaoguang, H. (2007), Electricity consumption and economic growth in China: cointegration and co-feature analysis. Energy Economics, 29(6), 1179-1191.

Zapata, H.O., Rambaldi, A.N. (1997), Monte carlo evidence on cointegration and causation. Oxford Bulletin of Economics and Statistics, 59(2), 285-298.