Original Research Article

Electricity consumption and economic growth in Kenya: an ARDL bound test approach

Abstract

The purpose of this study is to analyze the causal relationship that exist between economic growth and electricity consumption in Kenya for the sample period 1990 to 2022 using ARDL bound framework. ARDL F-test is used to estimate the existence of a long-run equilibrium relationship as well as the short-term dynamics that exists between the variables. At 10% confidence level, the study provides evidence of the existence of a cointegration relationship between economic growth and electricity consumption as the calculated F statistics is greater than the upper bound I(1) . The ECM model has an error correction term that is negative and significant at 5% level, supporting the existence of a cointegration relationship. For a shock in the GDP-energy consumption system, there is a 15.6% rate of adjustment to equilibrium. In the short-run, an increase in electricity consumption by 1% induces an increase in GDP growth by 0.69%. In addition, the diagnostics test shows that ECM model residuals have a constant variance, no correlation and normally distributed. In the long-run, electricity consumption has a positive effect on GDP growth. Granger causality test is used to determine the direction of causal link between the variables. The study provides evidence of unidirectional causal flow from GDP to electricity consumption at 10% confidence level. But there exists no causal flow from electricity consumption to GDP. Kenya is confirmed to fall in the conservation hypothesis. This implies that economic growth plays a critical role in electricity consumption growth rate.

Keywords: Causal flow; ARDL; GDP growth; electricity consumption.

1 Introduction

Energy supply and use has tendency to impact on human activities. Energy has been identified as a key determinant in production among capital, labor and land. In Kenya energy has been identified as a key enabler in its long term and short term development plans. Energy security has been treated as a national priority, with sustainable reliable and quality energy being essential gradient in attaining industrialized middle income economy by year 2030. The major source of energy in Kenya are coal, coke, hydro power, geothermal, solar and liquid fuels. The causal relationship between economic growth and energy consumption fall in four proposed hypothesis (Belke et al. 2010, Solow 1987). The first proposed hypothesis is the growth hypothesis where the causal flow is from energy to economic growth. The second hypothesis is the conservation hypothesis where the causal link from economic development to energy consumption. The third hypothesis is the feedback hypothesis that stipulates a two way causal flow between energy consumption and economic growth. The fourth hypothesis is the neutral hypothesis where there is no causality between the two variables.

The nexus of electric consumption and economic growth has attracted several research activities. Shiu and Lam (2004) applied error correction model to investigate the relationship between economic growth and electricity consumption in China from 1971 to 2000. The study provided evidence of a long-run equilibrium relationship and unidirectional causal flow from electricity to real GDP. Wolde-Rufael (2006) used bound test and Granger causality to analyze the long-run and causal relationship between GDP per capita and per capita electricity consumption in 17 Africa countries from 1971 to 2001. The study established that out of the 17 countries; there were cointegration relationship in 9 countries, 6 countries with bidirectional causality and 6 countries with unidirectional link from real GDP to per capita electricity consumption. Akinlo (2008) examined the economic growth and energy consumption nexus for eleven sub-Saharan Africa countries using ARDL bound test for the sample period 1980 to 2003. The study provided evidence of cointegration relationship in Sudan, Ivory coast, Ghana, Senegal, Gambia, and Zimbabwe with negative results for Kenya, Cameroon, Togo, Nigeria and Congo. The study provide evidence of bidirectional causal link in Ghana, Senegal and Gambia. In Zimbabwe and Sudan, the causal flow is from economic growth to energy consumption. No causal link exists for Kenya, Togo, Nigeria Ivory coast and Cameroon for the period under consideration. Odhiambo (2009) study showed a bidirectional causal flow between electricity consumption and economic growth in South Africa, both in the short-run and long-run, using tri-variate causality framework.

Odhiambo (2010) compared Kenya, South Africa and Congo relationship between economic growth and energy consumption by use of ARDL bound test in a multivariate framework. The study showed that Kenya and South Africa had a unidirectional causal link from energy consumption to economic growth while in Congo the causal flow is from economic growth to energy consumption. Ouédraogo (2010) used bound test to provide evidence of a cointegration between GDP and electricity consumption in Burkina Faso for the period 1968 to 2003. The Granger causality test resulted to a bidirectional causal flow between the variables. Tang and Tan (2012) provided evidence of long-run equilibrium relationship and bidirectional causality between economic growth and electricity consumption in Portugal over the sample period 1974 to 2008. Bélaïd and Abderrahmani (2013) study showed bidirectional causal flow between GDP and electricity consumption in Algeria from 1971 to 2010 using VECM framework. Dogan (2014) used Johansen cointegration test to investigate the relationship between economic growth and energy consumption in 4 sub-Saharan Africa countries namely Kenya, Zimbabwe, Benin and Congo for the period 1971 to 2011. There was no cointegration in any of the countries. The Granger causality test indicated unidirectional causal link from energy consumption to economic growth in Kenya and no causality in Zimbabwe, Benin and Congo. Nazlioglu et al. (2014) proved the presence of a bidirectional causal link between economic growth and electricity consumption in Turkey form 1967 to 2007. The study also concluded there existence of a cointegration relationship between the variables.

Iyke (2015) provided evidence of a long-run equilibrium relationship between economic growth and electricity consumption in Nigeria from 1971 to 2011 using a VECM framework. The direction of causal flow is from electricity consumption to economic growth both in long-run and short-run. Ameyaw et al (2016) established a unidirectional link from GDP to electricity consumption in Ghana for the period 1970 to 2014. The study also provided evidence of a cointgration relationship from a VECM analysis of the Cobb-Douglas growth model. Ali et al. (2020) established a cointegration relationship between urbanization, electricity consumption and economic growth in Nigeria for the period 1971 to 2014. The study also proved the existence of unidirectional causal flow from electricity consumption to economic growth. Hassan et al. (2022) analyzed electricity consumption impact on economic growth in Finland, Portugal and France using structural cointegration analysis.

The study provided evidence of a long-run equilibrium relationship in Portugal and Finland, while the short-term dynamics were not significant in France.

The aim of this study is to analyze the nexus between economic growth and disaggregate level of energy consumption that is defined as electricity consumption in Kenya considering the recent years. Technically, it entails determining the exist, if any, of a short run dynamics and long-run equilibrium relationship. The causal link between the two variables is also considered for examination.

2 Methodology

2.1 Data

This empirical study used annual time series data for the period 1990 to 2022. The dependent variable for the study is economic growth which is represented by annual GDP market price(Gross domestic product) in Ksh Millions while the independent variable is electricity consumption (ELC)in terms of Gwh (gigawatts hours). The dataset is obtained from the Kenya nation bureau of statistics (KNBS). A log transformation on both variables is performed to dampen theirs variance and remove outlier effect. The function form of the model in this study is

$$GDP = f(ELC) \tag{2.1}$$

From the data, GDP value has been experiencing almost linear growth rate from 1990. On the other hand, ELC experienced a disturbance in its linear growth around the in the neighborhood of year 2000.

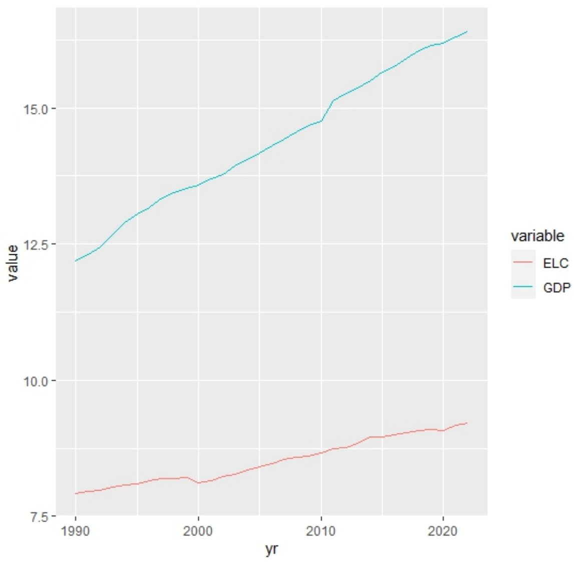

Figure 1: Variable plot

2.2 Model

2.2.1 ARDL model

The proposed linear model for this study is

$$y_t = \alpha + \lambda X_t + \epsilon_t \tag{2.2}$$

where y_t and X_t are two independent scalar variable times series. The autoregressive distributed lag model (ARDL(p,n)) of order p and n for equation (2.2) is given as

$$y_t = \alpha + \sum_{i=1}^{p} \rho_i y_{t-i} + \sum_{i=0}^{n} \lambda_i X_{t-i} + \epsilon_t \tag{2.3}$$

In lag operator L form, equation (2.3)reduces to

$$\rho(L)y_t = \alpha + \lambda(L)X_t + \epsilon_t \tag{2.4}$$

for $\rho(L) = 1 - \rho_1 L - \cdots - \rho_p L^p$

By considering the variables, equation (2.4) is given as

$$\rho(L)GDP_t = \alpha + \lambda(L)ELC_t + \epsilon_t \tag{2.5}$$

Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC)techniques are used to choose the lags p and q The equations for AIC and BIC are as given below;

$$AIC = 2k + 2ln(L)$$

$$BIC = kln(n) + 2ln(L)$$

Where k is the number of independent variables, n is the number observations and L is the maximum likelihood estimate of the model.

Table 1 show information score. The best combination is an ARDL(1,1), as it has the least score of -88.26 and -78.22 for AIC and BIC respectively. The first lag of GDP and electricity consumption fits well in the analyses of the nexus that exist between the two variables.

Table 1: Information score

GDP	ELC	AIC	BIC
1	1	-88.26	-78.22
1	2	-85.31	-74.10
1	3	-80.68	-68.37
2	1	-84.00	-72.79
2	2	-83.37	-70.75
2	3	-78.80	-65.13
3	1	-80.63	-66.96
3	2	-80.63	-66.96
3	3	-79.79	-64.75

Table 2 show the estimates for equation (2.5), which indicates that ARDL(1,1) model is statistically significant at 5% level. There is evidence of GDP first having a significant positive impact on GDP growth at 5% level. Electricity consumption without lag has a significant positive effect on economic growth, however, the first lag effect on GDP growth is not significant.

Table 2: ARDL model parameter estimates results

Parameter	estimate	p value
α	-1.1682	
λ_0	0.6442	0.0152
λ_1	-0.2797	0.3043
ρ	0.8727	0.0001
	R-squared: 0.9984 F-statistic = 5856 $\sim$ F(3,28) p-value: <2.2 $\times 10^{-16}$	

2.2.2 Bound test

For an invertible polynomial ie $\rho^{-1}(L)$, then equation (2.4) reduces to

$$y_t = \alpha^* + \frac{\lambda(L)}{\rho(L)} x_t + \nu_t \tag{2.6}$$

where $\rho^{-1}(L) = \frac{1}{\rho(L)}$, $\nu_t = \rho^{-1}(L)\epsilon_t$ and $\alpha^* = \rho^{-1}(L)\alpha$

Expanding $\rho^{-1}(L)$ in equation (2.6) results to an infinite distributed lag representation (Hassler and Wolters 2006)

$$y_t = \alpha^* + (\sum_{j=0}^{\infty} \rho_j{}^* L^j)(\sum_{j=0}^{n} \lambda_j L^j) x_t + \nu_t = \sum_{j=0}^{\infty} \sigma' x_{t-j} + \nu_t \tag{2.7}$$

By re-parameterization of equation (2.7) and considering the first difference for the variables (Pesaran and Shin 1995), then equation (2.7) final form that contains error correction model(ECM) and long-run equilibrium relations is given as

$$\Delta y_t = \theta + \sum_{i=1}^{p} \phi_i \Delta y_{t-1} + \sum_{j=0}^{n} \beta_j \Delta x_{t-1} + \delta_1 y_{t-1} + \delta_2 x_{t-1} + \iota_t \tag{2.8}$$

Considering the variables, equation (2.8) reduces to

$$\Delta GDP_t = \theta + \sum_{i=1}^{p} \phi_i \Delta GDP_{t-1} + \sum_{j=0}^{n} \beta_j \Delta ELC_{t-1} + \delta_1 GDP_{t-1} + \delta_2 ELC_{t-1} + \iota_t \tag{2.9}$$

Bound test (Pesaran et al.2001)involves F types test statistics for cointegration on equation (2.8). The test statistics has two bounds, namely; the upper bound I(1) and the lower bound I(0). The null hypothesis is there is no cointegration ie δ_r. If the calculated F statistic is greater than the upper bound, reject null hypothesis and there exist cointegration. If the calculated F-statistics is smaller than the lower bound, fail to reject the null hypothesis, there evidence of no cointegration. In scenario where the calculated F statistic falls within the two bounds, the test is deemed inconclusive.

From table 3, there is evidence of cointegration at 10% confidence level, as calculated F statistics (5.2266) is greater than the upper bound I(1) which is 5.05. However, the calculated F statistics is slightly smaller than the lower bound I(0) at 5% significance level.

In the presence of cointegration, the short term dynamic equation (ECM) from equation (2.8) is given as;

Table 3: Pesaran, Shin and Smith Cointegration test results

	F-test	
	I(0)	I(1)
10% critical value	4.225	5.05
5% critical value	5.29	6.175
F-statistic = 5.2266		

$$\Delta GDP_t = \theta + \sum_{i=1}^{p} \phi_i \Delta GDP_{t-i} + \sum_{j=0}^{n} \beta_j \Delta ELC_{t-j} + \varphi ECT_{t-1} + \xi_t \tag{2.10}$$

where ECT_{t-1} is the error correction term. The estimates for the ECM model as shown in table 4.

Table 4: Error Correction Model results

Parameter	estimate	p value
θ	-1.4175	
φ	-0.156	0.0027
β_0	0.6878	0.0077

The ECM support the presence of cointegration as the error correction term is negative and significant at 5%. For a shock in the GDP-energy consumption system, there is a 15.6% rate of adjustment to equilibrium. In the short-run, an increase in electricity consumption by 1% induces an increase in GDP growth by 0.69%.

Table 5: ECM Model diagnostics results

test	statistic	p value	distibution	test for
Breusch-Godfrey Test	0.4025	0.5313	F(1,26)	residual correlation
Ljung-Box Test	0.4818	0.4876	χ^2 (1)	residual correlation
Breusch-Pagan Test	2.0164	0.569	χ^2 (3)	constant variance
Shapiro-Wilk normality test	0.7538	0.06		Skewness & kurtosis
Ramsey's RESET Test	0.6216	0.5449	F(2,26)	functional form of the model

The diagnostics of ECM model are as shown in table 5. There is no heteroskedasticity and residual serial correlation in the data. The ECM functional model form is perfect and the error terms are normally distributed.

Robustness test

The CUSUM test, CUSUMSQ test and MOSUM test proposed by Brown et al. (1975) and Chu et al. (1995) are used to check model stability. CUSUM test assess the stability of the ARDL model coefficients based on the sequence of sum of the standardized one step ahead forecast error. On the other hand CUSUMSQ test uses the sequence of recursive residual sum of square to check the model stability. MOSUM test structural changes by considering moving sum of the recursive residual. Figure 3 represent robust tests plots at 5% significance level. The CUSUM and MOSUM residual fluctuates around zero without crossing the critical lines, which indicates there is no sign of change in the coefficients over time. However, the recursive CUSUMSQ test indicates evidence of weak instability in the volatility of coefficients for the period 2005 to 2006 as the series touches the 5% limits.

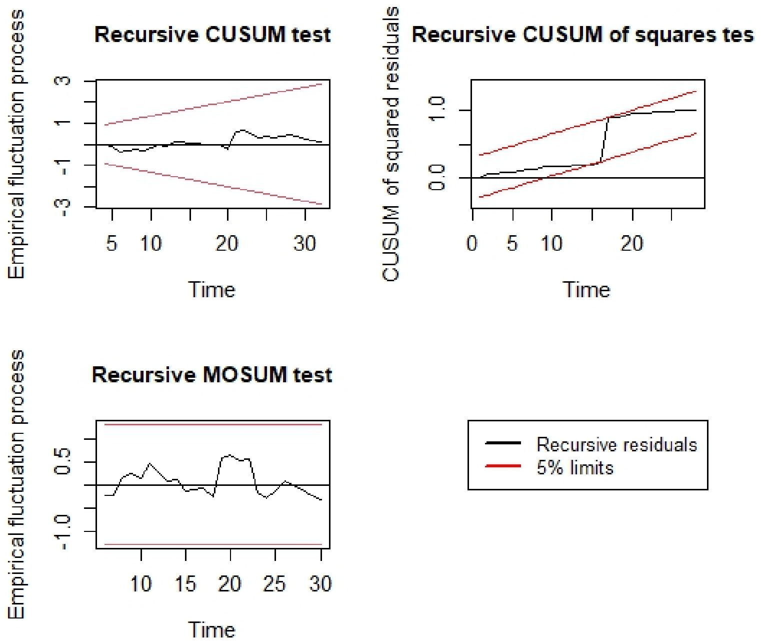

Figure 2: Robustness test result

The long-run equilibrium relation derived from equation (2.8) is given as

$$GDP_t = \theta + \sum_{i=1}^{k} \phi_i GDP_{t-i} + \sum_{j=0}^{l} \beta_j ELC_{t-j} + \mu_t \tag{2.11}$$

The estimates for the long-run equation are as shown in equation (2.12).

$$GDP_t = -1.4175 - 0.1564GDP_{t-1} + 0.4431ELC_{t-1} \tag{2.12}$$

Economic growth and electricity have proved to have a long-run equilibrium relationship. In the equilibrium state, the first lag of GDP has a negative effect on GDP while the first lag of electricity consumption has a positive effect. The existing cointegration relationship is a shown in figure 3. The equilibrium state was in depressed state the year 1999, though the state has improved with time.

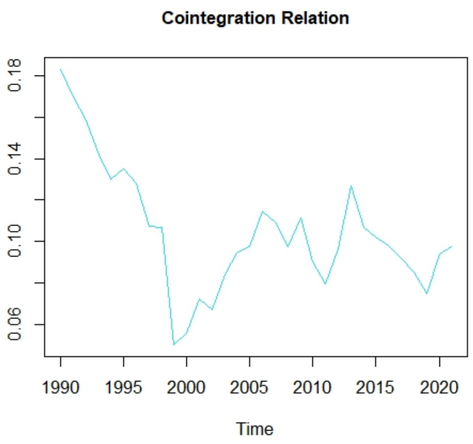

Figure 3: Cointegration relationship plot

2.2.3 Granger causality

Granger (1969) developed a test for testing the causal relationship between two variables in a short time spectrum. The test states that for any observed series Y_t causes an observed series X_t if

$$\sigma^2(X|U) < \sigma^2(X|\overline{U-Y})$$

The Granger causality model in autoregressive lag length (p) is given as (Hamilton [10])

$$X_t = c_t + \kappa(L)X_{t-1} + \eta(L)Y_{t-1} + \upsilon_t \tag{2.13}$$

The test statistic for test is given as:

$$\frac{(RRS_0 - RSS_1)/p}{RSS_1/(T-2p-1)} \sim F(p, T-2p-1)$$

where RRS_1 is the sum of squared residuals from equation (2.13) and RRS_0 is the sum of squared residual for x_t under the null hypothesis.

The two hypotheses of Granger causality test are as follows:

Ho: $\eta_i = 0$ for all i. The null hypothesis model given as

$$X_t = c_0 + \gamma(L)X_{t-1} + \tau_t \tag{2.14}$$

Ha: $\eta_i \neq 0$.

Table 6: Granger causality result

Granger-cause	F-Test	p value
GDP	3.0712	0.0903
ELC	1.2186	0.2787

From table 6, there is evidence that GDP growth granger cause energy consumption at 10% confidence level. However electricity consumption in Kenya does not granger cause GDP growth. The causal flow is therefore unidirectional from GDP to electricity consumption. Growth in GDP results to an increase in electricity consumption over the sample period 1990 to 2020.

3 Conclusions

The study sort to establish existence of a significant cointegration relationship and the causality direction in the electricity consumption and economic growth nexus. Electricity consumption and economic growth in Kenya have proved to have linearly increased over time. An ARDL (1,1) is estimated, which is significant at 5% level. The first lag of GDP and in level electricity consumption is significant in GDP growth while the impact of electricity consumption first lag is not significant. The bound test indicates the presence of a cointegration relationship between the electricity consumption and economic growth nexus as at 10% significance level. The presence of cointegration is also supported by a negative and significant error correction term in the ECM model. The rate of adjustment to equilibrium status for a shock in electricity consumption - economic growth nexus is 15.6%. In the short-run, an increase in electricity consumption by 1% induces an increase in GDP growth by 0.69%. Economic growth and electricity have proved to have a long-run equilibrium relationship. In the equilibrium state, the first lag of GDP has a negative effect on GDP while the first lag of electricity consumption has a positive effect. The Granger causality provides evidence of unidirectional causal flow from economic growth to electricity consumption in Kenya at 10% significance level. The electricity consumption and economic growth relationship in Kenya follows conservation hypothesis, in which growth in GDP results to an increase in electricity consumption.

The implication of conservation hypothesis is as GDP continually increase, the demand for electricity increases. This call for more investments in generation to match with the annual increasing demand as well as electricity distribution network development to make electricity available to households and industrial purposes. Energy sector policy and regulatory framework should emphasize on matching effectiveness of impact generated by economic measures and policy geared toward economic growth. I would recommend future studies on the effect of renewable energy on economic growth doubled with the international theme of zero carbon emission agenda.

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