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Evidence of Causality between Economic Growth and Electricity Consumption Expenditure in Uganda

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study is to investigate the evidence of causality between economic growth and electricity consumption expenditure in Uganda for the period 1986 to 2017, aimed at contributing to literature on this topic and inform energy policy design in the country. Unlike previous studies on the causal link between energy consumption and economic growth, this paper introduces in capital stock as an intermittent variable in the causality framework. In this paper, we employed Johansen (1988, 1995) multivariate Cointegration and Vector Error Correction Model (VECM) based on Granger causality tests. Findings revealed a bi-directional causality between electricity consumption and economic growth in the long-term and distinct causal flow from economic growth to electricity consumption in the short-term and long-term Granger causality from capital stock to economic growth, with short-run feedback in the opposite direction. Therefore, the Government of Uganda should implement conservation policies only through reducing energy intensity and promoting efficient energy use to avoid decline in output but also strengthen its efforts towards capital accumulation in order to realize sustainable economic growth and meet the desired goal of sustainable energy for all.

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1. INTRODUCTION

The importance of electricity consumption in the economic and social development through improved quality of life cannot be overemphasized [1]. Electricity as a form of energy is an essential driving force of economic growth in all economies, which directly and indirectly complement labour, capital and land as factors of production [2]. Electricity contributes to economic growth through employment generation, and leads directly to value addition associated with extraction and transformation of inputs, technology transfers, marketing and distribution of goods and services. Moreover, it also strengthens modernization of traditional economic sectors and promotes continuous expansion of secondary and tertiary sectors of the economy, in addition to improving the quality of life of individuals, particularly through heat, light and use of electrical appliances. The above withstanding, [3] highlighted a number of factors affecting electricity consumption amongst which are; population growth, economic performance, consumer attitudes and technological advancements.

In a review by [4] on a sample of 136 research papers focusing on the nexus between energy consumption and economic growth, indicated that; 41% concluded on the validity of the feedback effect, 25% concluded on the validity of the growth hypothesis, and 21% supported the conservation hypothesis while 13% were centered on the neutrality hypothesis. There is thus a lot of debate surrounding the issue of the relationship and/or the direction of causality between economic growth and electricity consumption expenditure and todate this subject has not been resolved as it continues to yield conflicting results in different country settings. This is because of the important policy implications that can be derived from this relationship regarding the course of action that can be done to accelerate economic growth and encourage electricity consumption. In spite of a wide discussion in literature (see; Table 1 and Table 2), the issue of the direction of causality between electricity consumption and economic growth remains ambiguous. This ambiguity hinges on the use of different data sets, different methods of analysis and different country characteristics [5]. In addition, some studies have over-relied on a bivariate causality framework, which may suffer from the omission of variable bias. This is because; incorporating additional variables that affects both electricity consumption and economic growth may change not only the direction of causality between the two variables but also the magnitude of the estimates.

To this end, considering the highlighted developments and prior works so far undertaken on electricity- growth nexus (see; Table 1), the aim of this research is to empirically examine the evidence of causality between electricity consumption and economic growth in Uganda by incorporating in our framework a third variable (Capital stock) and using the Cointegration approach. The introduction of the third variable in our model may help provide more explanation and understanding of the direction of causality between economic growth and electricity consumption expenditure in the context of a least developed country (Uganda) which will help the government of Uganda in developing appropriate policies with regard to electricity consumption and the economy.

The above withstanding, since the widespread adoption of Cointegration techniques, evidence on whether there exists a long-run relationship between output and electricity consumption has yielded mixed results. As such, [6] found cointegration between output and energy consumption for (India, Malaysia and Pakistan). Nonetheless, scholars such as [7] reported lack of evidence of a long-run equilibrium association. More so, [7] found causality running from GDP to energy consumption without feedback in Taiwan. Thus, from the foregoing arguments and to the best of the author’s knowledge, there is limited empirical evidence on the relationship between electricity consumption expenditure and economic growth in literature for Uganda. Based on this gap and introducing in our model a third variable (capital stock) as an intermittent variable, we employed a trivariate causality framework in order to understand the causality between economic growth and electricity consumption expenditure in a least developed country Uganda. To achieve this aim, the following specific research objectives guided the study:

i. To investigate existence of Cointegration between economic growth and electricity consumption expenditure in Uganda.

ii. To investigate the direction of causality between economic growth and electricity consumption expenditure in Uganda.

The rest of the paper is structured as follow; section one contains the introduction together with an overview of electricity sub-sector in Uganda. In section two, we present a detailed review of relevant literature on electricity consumption expenditure and economic growth. Section three dwells on the data and methodology followed. Section four presents the results and discussion of findings while section five looks at the conclusion and policy implications.

1.1 Overview of the Electricity Sub-Sector of Uganda

Uganda is one of the few African countries that fully unbundled the electricity sector, transferred the role of the government in the subsector to the private sector participation. The reforms in this subsector that came with unbundling aimed at creating efficiency in the subsector with minimal government intervention [8]. To this end [9] indicates that, the subsector is run under a liberalized set up following its liberalization in 1997 and the enactment of the electricity Act, 1999. Additionally [9] indicates that, the Act mandated the unbundling of Uganda Electricity Board (UEB) which had the sole responsibility for generation, transmission, distribution, sale, import and export of Uganda's electricity. Lately, the supply industry of electricity is regulated under the Electricity Act, 1999, Chapter 145, the energy Policy, the National Environmental Act, Chapter 153 and the Statutory Instruments and Guidelines issued by the Electricity Regulatory Authority (ERA). More so, [9] further adds that, the supply industry of electricity is structured into three segments, namely: Generation, Transmission, and Distribution.

To this end, Uganda's power generation is mainly diversified across Four (4) different sources namely: hydro (1,023.59 MW), Thermal (100 MW), Cogeneration (63.9 MW), and Grid-connected Solar (60 MW) [9]. In 2001, Uganda had only three plants generating electricity but this number has since increased to over 40 plants and is continuing to grow. More so, by 1954, the total installed generation capacity of electricity was only 60 MW but this number has been increasing steadily with the establishment of new plants [9]. Moreover, in 2000 the installed capacity had increased to 400MW and since then this increased to 1237.49 MW as of October 2020 with the expectation of a further increment to 1837.49 MW by 2021 [9]. It is noted that, as Uganda continue to focus intensely on grid-based generation, by 2023, the country will create about 2,700 MW of surplus supply if the generation is established following the current government ambitious plans. However, increasing supply must be paid for whether it is utilized or not. More so, a surplus may turn out to be costly. Notably, a USD 0.10/kWh take-or-pay power purchase agreement may turn out to be USD 0.20/kWh if only half of the power was used. In Uganda, the mismatch between supply and demand could increase total electricity costs by over USD 950 million per year and increase the cost of service to more than USD 0.30/ kWh. While the losses associated with transmission and distribution continue to reduce, a lot remains undone. Moreover, constraints in transmission and distribution systems and their interconnection deter the use of existing supply to around 693 MW regardless of the installed capacity. The Ministry of Energy and Mineral Development priority and issue paper of 2019 projected that this bottleneck is suppressing around 450 MW of potential near-term demand, surging the cost of service by a further USD 0.10 kWh and increasing cost due to unutilized capacity by USD 125 million per year by 2023 [10].

While we observe the Uganda's commitment to increase the amount of electricity generation, paradoxically, some parts of the country continue to experience load shedding. Despite the government efforts to increase the amount of electricity generated in Uganda, the sector remains relatively underdeveloped [11]. Moreover, [12] noted that, households that had access to grid-connected electricity by 2014 only totaled to 4.4%. This makes Uganda's percapita electricity consumption one of the lowest in the whole world. According to [12], Uganda's electricity consumption in 2012 was estimated at 80 kWh percapita. Hydropower plants dominates generation capacity of electricity in Uganda with support from heavy fuel oil coupled with biomass cogeneration power plants. However, erratic rains and droughts affect hydropower plants and this in turn adversely affects the power supply in the country.

2. REVIEW OF RELATED LITERATURE

Various Prediction approaches utilized by researchers in studying the nexus between electricity consumption expenditure and economic growth may be structured into two categories: causal relationship models and univariate models [1]. Doroodi et al. [1], argued that, causal relationship models predict dependent variables based on one or several variables and show that there is a causal relationship between the dependent and independent variables. However, univariate models validate that a system is a function of its behaviour [13].

Drawing from the works of [14] a plentiful of studies in literature have widely explored the direction of the causal relationship between electricity consumption and economic growth measured in terms of GDP, and its policy implications based on four main hypotheses, namely; growth, conservation, feedback and neutrality as observed earlier. In a recent study by [15] using literature survey to investigate stationarity, cointegration, and direction of causality between energy consumption and economic growth for the period 1974-2021 and testing the four established hypotheses of feedback, growth, conservation and neutrality noted that, results are thoroughly mixed with no agreement, some studies were explicit on the degree to which results were contentious. Again, [15] indicated a lack of consensus for both country specific as well as panel based studies. Overall, [15] found the growth hypothesis to be the most dominant outcome for country based studies. Moreover, findings indicated that the debate is inconclusive with growth hypothesis accounting for 43.8%, feedback 18.5%, conservation 27.2%, and neutrality hypothesis 10.5% for country specific studies.

The growth hypothesis presupposes that the economy depends on energy consumption for economic growth so that the more energy the economy consumes, the more the economy will grow. Thus, energy consumption drives economic growth. In this case, any energy shortage or supply interruption will have a negative effect on economic growth. Under this hypothesis, electricity conservation measures aimed at reducing energy consumption may negatively affect economic growth. This hypothesis is supported by studies that found unidirectional causal flow from energy consumption to economic growth [16-19] and [20]. Moreover, in a study by [21] on energy consumption and economic growth in Vietnam using the Neoclassical Solow growth framework for the 1871-2011 period revealed a unidirectional causality running from energy consumption to economic growth.

On the other hand, the conservation hypothesis asserts that energy consumption depends on the growth of the economy implying that, the more growth the economy experiences, the more energy will be demanded and consumed to support that growth. Thus, economic growth is not strongly dependent on energy consumption. Under this hypothesis, energy conservation policies such as efficiency improvement measures and demand management policies aimed at scaling down electricity use by decreasing wasteful use of electricity can be initiated without negatively affecting economic growth [22]. Researchers such as [23,18,5,24] support this hypothesis. These researchers found a unidirectional causality from economic growth to energy consumption. Moreover, the feedback hypothesis postulates that energy consumption and economic growth are interrelated and may complement each other. In this case, efficient energy use and energy development policies geared toward increasing electricity generation can influence economic growth positively.

Empirical studies such as [25-27] and [6] found a bidirectional causality between energy consumption and economic growth supported this hypothesis. Lastly, the neutrality hypothesis posit that energy consumption expenditure and economic growth are not causally related. This hypothesis suggests that, neither the conservative nor the expansive policies in relation to energy consumption expenditure have any effect on economic growth. Various studies [28-30] and [31], empirically supported this hypothesis. However, [31] applying the Johansen Co-integration test in assessing causality between energy consumption and economic growth in India, found that energy consumption, economic growth, capital and labor were cointegrated. Against this backdrop, Table 1 provides a summary of studies undertaken on the nexus between energy consumption and economic growth in various jurisdictions. Notably, available evidence suggests a dearth of research on the nexus between electricity consumption expenditure and economic growth from the Ugandan context.

Table 1. Summary of research on the causality between energy (electricity) and economic growth

References	Methodology utilized	Hypothesis to be tested
[14] 1947-1974	Standard granger causality	Growth-led energy USA
[28] 1973-19744	Standard granger causality	Growth-led energy USA
[29] 1973-1981	Standard granger causality	Growth-led energy Korea
[32] 1950-1992	Vector error correction model granger causality	Growth-led energy, Italy, Japan, South Korea.
[33] 980-2003	Auto Regressive Distributive Lag Bounds test (ARDL)	Neutrality. Nigeria, Cameroon, Ivory Coast, Kenya, Togo.
[20] 1971-2001	Toda and Yomamoto Granger causality test	Growth-led energy, Algeria, Congo, Egypt, Ghana, Ivory Coast.
[33] 1980-2003	Full modified OLS	Energy-led-growth-led –energy, Ghana, Gambia, and Senegal.
[34] 1975-2001	Vector Error Correction Model Granger Causality.	Energy-led-growth, Ghana.
[35] 1975-2006	Vector Error Correction Model Granger Causality.	Energy-led-growth, Ghana.
[36] 1960-1999	Toda and Yomamoto	Energy-led-growth-led-energy, Philippines.
[37] 1948-1994	Cointegration, Granger causality.	Energy-led-growth, U.S.A
[38] 1961-1997.	Cointegration, VEC Granger causality.	Energy-led-growth-led-energy, Canada.
[39] 1966-2002	VEC Granger causality	Energy-led-growth, Hong Kong.
[40] 1960-2000.	Toda and Yomamoto Causality test	Neutrality.
[28] 1949-2006	Toda and Yomamoto Causality test	Neutrality.
[41] 1952-1992.	VEC Granger causality	Energy-led-growth-led-energy (Taiwan). Energy-led-growth (South Korea).
[42] 1968-2005.	Granger causality, Bounds testing.	Growth–led-electricity, Turkey.
[27] 1972-2003	ECM based F-test, ARDL	Growth-led-electricity-led-growth, Malaysia.
[43] 1960-1998	Standard granger causality	Electricity-led-growth, Sri Lanka.
[44] 1971-2000	Cointegration, Error Correction Model	Growth-led-electricity-led-growth, China.
[16] 1971-2006	Auto Regressive Distributed Lag Bounds test	Electricity-led-growth
[26] 1971-2006	Standard granger causality	Growth-led-electricity-led-growth, South Africa.
[45] 1980-2006	VEC Granger causality	Electricity-led-growth, Nigeria.
[46] 1970-2006	ARDL test	Growth-led-electricity, India.
[47] 1950-1997	Standard granger causality	Growth-led-electricity, India.
[18] 1996-1999	Multivariate Granger causality	Growth-led-electricity, Australia.

Source: *Adapted from [5] Pg. 20-21*

Table 2. Comparison of empirical results from causality tests for developing countries

Author	Countries and period	Causal relation
[48]	South Korea, Philippines (1954- 1976)	GDP → Energy
[6]	Malaysia, Singapore, Philippines, India, Indonesia, Pakistan (1955-1990)	Mixed
[49]	Sri Lanka and Thailand (1955-1991)	Energy → GDP
[50]	Taiwan (1954-1997)	Energy ↔ GDP
[32]	Argentina, South Korea, Turkey, Indonesia, Poland (1950-1992)	Mixed
[36]	India, Indonesia (1960-1999)	Energy → GDP
	Thailand and Philippines (1960-1999)	Energy ↔ GDP
[43]	Sri Lanka (1960-1998)	Energy ↔ GDP
[51]	South Korea (1970-1999)	Energy ↔ GDP
[52]	India (1950-1996)	Energy ↔ GDP
[34]	18 countries (1975-2001)	Energy → GDP
[53]	Congo (1960-1999)	GDP → Energy
[54]	China (1971-2002)	Energy → GDP
	India (1971-2002)	GDP → Energy

Source: *adapted from Lee [34] pg. 417.*

We deduce from Tables 1 and 2 that, the relationship between energy consumption and economic growth as measured by GDP in various countries developing and developed alike, presents many contradictory results. These contradictions in results thus generalization in the policy conclusions that could be made for various countries. These results suggests further that, different countries have unique characteristics when it comes to electricity consumption expenditure and are at completely different stages of growth. Countries like Taiwan, Thailand and Philippines indicated lack of convergence in study results. From Table 2, [50] found a bidirectional causality between energy consumption and income, and again between coal and electricity consumption. In the same study, [50] found a unidirectional causality from GDP to oil consumption and from the consumption of gas to GDP. In a spell of five years, [55] concurred with [50] on the bidirectional association between income and the total energy as well as coal consumption. However, [55] rejected results by [50] indicating that, unidirectional causality moves from both oil and electricity consumption to economic growth and alluded that consumption of gas produces a stationary variable. Thus, questions about the link between electricity consumption expenditure and economic growth are here to stay.

3. METHODOLOGY

3.1 Data Types And Sources

This paper utilized annual time series data for Uganda covering the period from 1986 to 2017. The data used as a proxy for economic growth is gross domestic product (GDP) (US$, 2005 constant prices). Capital stock is proxied by gross fixed capital formation (US$ 2005 constant prices). We obtained data for these two series from the World Bank Development Indicators (WDI) database. Lastly, researchers obtained data on electricity consumption (measured in thousands of kWh per capita) from Uganda Bureau of Statistics (UBOS) Statistical abstracts.

3.2 Model Specification

To determine the short-run and long run causal effects between electricity consumption and economic growth, the study includes capital stock as an additional intermittent variable in the relationship to reduce on the specification bias, which is inherent in the bivariate causality framework [56] and [57]. Thus, the study specifies the following model for estimation:

$$\Delta LOGGDP_t = \emptyset_0 + \sum_{i=1}^{n} \emptyset_{1i}\,\Delta\, LOGGDP_{t-i} + \sum_{i=1}^{n} \emptyset_{2i}\,\Delta\, LOGEC_{t-i} + \sum_{i=1}^{n} \emptyset_{3i}\,\Delta\, LOGKF_{t-i} + \emptyset 4\, ECTt-1+ut \quad (1)$$

$$\Delta LOGEC_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\,\Delta\, LOGEC_{t-i} + \sum_{i=1}^{n} \alpha_{2i}\,\Delta\, LOGKF_{t-i} + \sum_{i=1}^{n} \alpha_{3i}\,\Delta\, LOGGDP_{t-i} + \alpha 4\, ECTt-1+\varepsilon t \quad (2)$$

$$\Delta LOGKF_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i}\,\Delta\, LOGKF_{t-i} + \sum_{i=1}^{n} \beta_{2i}\,\Delta\, LOGEC_{t-i} + \sum_{i=1}^{n} \beta_{3i}\,\Delta\, LOGGDP_{t-i} + \beta 4\, ECTt-1+vt \quad (3)$$

Where: *LOGGDP* is the natural logarithm of Gross Domestic Product , *LOGEC* is the natural logarithm of electricity consumption expenditure, *LOGKF* is the natural logarithm of gross fixed capital formation, ECT_{t-1} is the lagged error correction term derived from the long-run cointegrating relationship t, vt and ut are mutually uncorrelated white noise residuals, and the $\alpha's$, $\emptyset's$and $\beta's$are corresponding adjustment coefficients. In this test, the short-run causality is captured by the significance of the F –statistics and t − statistics on the explanatory variables. On the other hand, the long-run causality is captured by the significance of the t − statistic on the coefficient of the lagged error correction term. Nevertheless, if there is no Cointegration between the variables, equations (1), (2) and (3) are estimated without the error correction term and only short-run causality direction can be determined through F-test of significance of the explanatory variables.

3.3 Unit Root Tests

We investigated the presence of unit roots among the variables by employing three-unit root testing procedures, namely: The Augmented Dickey-Fuller (ADF) test, the Phillips Perron (PP) unit root test and the Zivot and Andrews [58] test. We selected the lag length in the ADF test using the Schwarz Bayesian Information (SBIC) criterion while the bandwidth for the PP test was selected with the Newey-West Bartlett kernel.

3.4 Cointegration Test

According to [59] and [60], the existence of Cointegration between the variables may imply the existence of causality between the variables at least in one direction. Having a multiple regression model for estimation, this research paper employs the Johansen-Juselius [61,62] multivariate Cointegration testing procedure to test for long-run associations between economic growth, gross fixed capital formation and electricity consumption expenditure in Uganda. The researcher utilizes the Schwartz- Bayesian information Criteria (SBIC) to choose the lag length in the Cointegration test and the number of linear independent cointegrating vectors, *r* where $0 \leq r < K$, *K* being the total number of variables in the regression is determined based on the Johansen's max-eigenvalue statistic and trace statistic. If variables are Cointegrated, then r > 0

3.5 Estimation Procedure

This research paper employs the vector error correction model (VECM) estimation framework to determine the short-run and long run causal effects between electricity consumption and economic growth. The VECM procedure was chosen to be the most appropriate estimation frame work for various reasons: (i) All the variables in the model are potentially endogenous (ii) All the variables in the model were integrated of order one (iii) There was evidence of Cointegration in the empirical model, and (iv) The VECM estimates enable causality analysis between the variables of interest.

4. RESULTS AND DISCUSSION

4.1 Basic Descriptive Statistics of the Model Variables

To understand data characteristics, the paper generates the basic descriptive statistics on the model variables in two forms: (i) when the variables are un-transformed, and (ii) when the variables are log-transformed. Table 3 shows the basic descriptive statistics of the un-transformed model variables while Table 4 shows the basic descriptive statistics of the log-transformed variables**.**

The descriptive statistics in Table 3 indicates that Uganda recorded a mean GDP of $ 11.2 billion over the period 1986-2017. The minimum GDP was $ 2.86 billion and the maximum was $8.26 billion. According to analysis of raw data,

Table 3. Basic descriptive statistics of the un-transformed model variables

Variable	Obs.	Mean	Min	Max	Std. Dev.
GDP (current US $)	32	11,200,000,000	2,860,000,000	27,300,000,000	8,260,000,000
EC (million Ugx.)	32	530,832	50	2,357,120	697,463
KF (Current $)	32	2,520,000,000	331,000,000	7,320,000,000	2,350,000,000

***Source**: Generated by the author from raw data*

Table 4. Basic descriptive statistics of the log-transformed model variables

Variable	Obs.	Mean	Min	Max	Std. Dev.
LOGGDP	32	22.8905	21.7732	24.0299	0.7110
LOGEC	32	11.4320	3.9120	14.6730	2.7524
LOGKF	32	21.2001	19.6188	22.7142	0.9742

Source: *own compilation by the author from raw data*

the minimum GDP was recorded in 1992 and the maximum GDP was in 2014. Table 3 also indicates that the mean consumption expenditure on electricity over the period 1986-2017 was 530,832 million Ugx. The minimum consumption expenditure on electricity was 50 million Ugx, and the maximum was 2,357,120 million Ugx. According to the analysis of raw data, the minimum consumption expenditure on electricity was recorded in the year 1986 while the maximum expenditure on electricity was recorded in the year 2017.

The key result for the descriptive statistics of the log-transformed variables as indicated in Table 4 is the measure of variability of the variables. For instance, the descriptive statistics in Table 4 show that the variable “LOGEC” had the largest variability (std. dev. =2.7524) while “LOGGDP” had the smallest variability (std. dev. = 0.711).

4.2 Normality Test on the Endogenous Variables

Regression theory requires that the dependent variable (and hence the error term) follows normal distribution. This research paper estimates a VECM to study causality between economic growth and electricity consumption. By adopting VECM, all the variables are taken to be cointegrating endogenously determined variables, that is to say, all the variables are potentially endogenous. In this case, we test for normality of all the log-transformed model variables. We achieved this through the generation of a histogram with a density normal plot for each log-transformed variable.

The histograms with normal plots in Figs. 1, 2 and 3 indicate that the variables: “LOGGDP”, “LOGEC” and “LOGKF” are approximately normally distributed. Regression analysis assumes normal distribution of the error term, which resembles the distribution of the dependent variable. In this paper, where we consider all the variables as endogenous in the VECM framework, all the log-transformed variables pass the normality requirement for regression analysis.

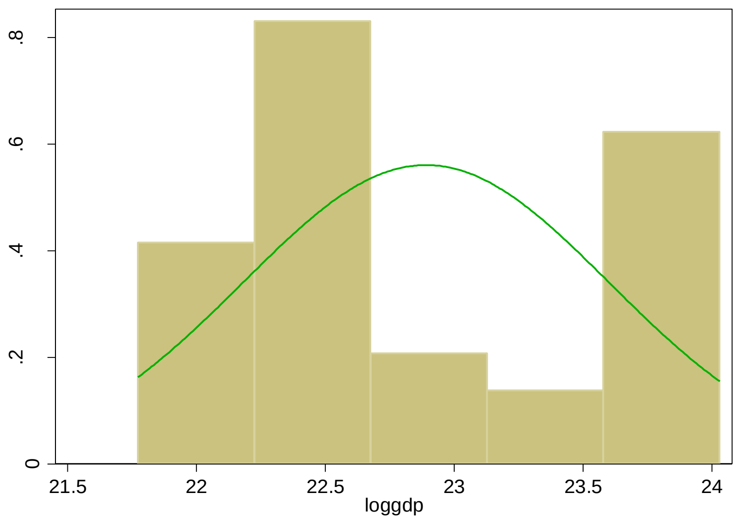

Fig. 1. Histogram with a Density Plot of “Loggdp”

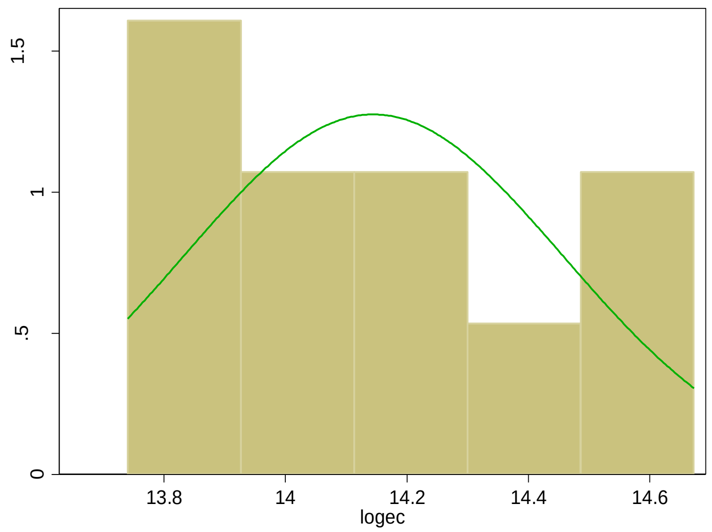

Fig. 2. Histogram with a Density Plot of "Logec"

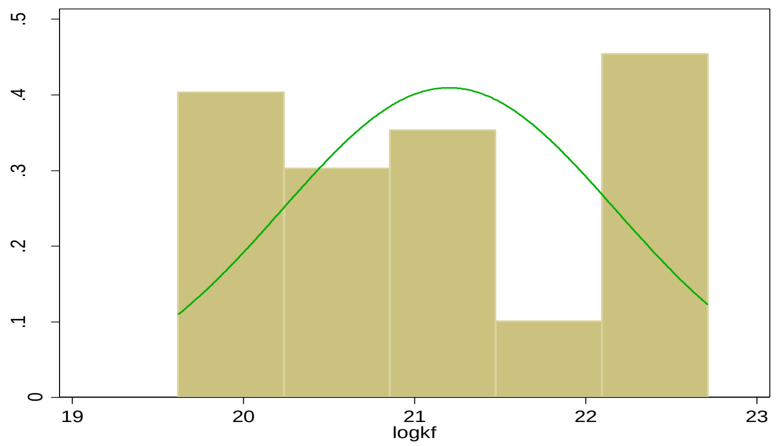

Fig. 1. Histogram with a Density Plot of "Logkf"

4.3 Unit Root Test Results on the Transformed Model Variables

Because the model variables enter the regression model when they are log-transformed, in this paper, researchers tested the unit roots on the log-transformed variables. We implemented three different unit root tests on each variable in levels and in its first difference (where applicable). Table 5. Show the summary of results from the adopted unit root tests.

Figures in parentheses are the critical values at 5% level of significance. ** indicate significance at 5 % level. The unit root test results summarized in Table 5 show that all the three unit root test methods adopted, do not reject the null hypothesis of non-stationarity for each variable in levels at 5% level of significance but the unit root tests reject the null hypothesis of non-stationarity of each variable in its first difference at 5% level of significance. Therefore, the unit root test results indicate that variables: "LOGGDP", "LOGEC" and "LOGKF" are integrated of order one, I (I).

4.4 Cointegration Test Results

Having established that all the model variables are integrated of order one, we implemented a

Table 5. Summary of the unit root test results on all model variables

	ADF Test		PP Test		Z-Andrews Test		Order of Integration
Variable	**Estimated Z-statistic when variable is in levels**	**Estimated Z-statistic when variable in first diff.**	**Estimated Z-statistic when variable is in levels**	**Estimated Z-statistic when variable in first diff.**	**Minimum t-statistic at break point when variable is in levels**	**Minimum t-statistic at break point when variable in first diff.**	
LOGGDP	-0.105 (-2.986)	-3.129** (-2.989)	-0.363 (-2.983)	-4.017** (-2.986)	-4.976 (-5.08)	-5.924** (-4.80)	I(I)
LOGEC	1.480 (-1.950)	-3.138** (-1.950)	1.920 (-1.950)	-3.429** (-1.950)	-3.742 (-4.80)	-5.740 (-4.80)	I(I)
LOGKF	-0.064 (-2.986)	-3.570** (-2.989)	-0.937 (-2.983)	-4.720 (-2.986)	-3.883 (-5.08)	-5.622** (-5.08)	I(I)

Source: *Compiled by the author from STATA*

Table 6. Lag order selection in the cointegration test

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-26.1824				.001614	2.08446	2.12809	2.22719
1	57.0199	166.4	9	0.000	8.1e-06*	-3.21571*	-3.04117*	-2.64477*
2	63.5596	13.079	9	0.159	9.9e-06	-3.03997	-2.73452	-2.04082
3	66.6993	6.2794	9	0.712	.000016	-2.62138	-2.18502	-1.19401
4	76.1554	18.912*	9	0.026	.000018	-2.65396	-2.08669	-.798387

Source: Generated by the author using STATA.

Table 7. A Summary of the Cointegration Test Results

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	3	27.423986	.	42.3741	29.68
1	8	43.207672	0.63879	10.8067*	15.41
2	11	48.399386	0.28463	0.4233	3.76
3	12	48.611017	0.01356		

Source: Generated by the author using STATA

cointegration test due to Johansen-Juselius [61,62]. Table 6 shows a summary of the lag order selection and Table 4.4.2 show a summary of the Cointegration test results.

On the basis of Swartz-Bayesians Information criteria (SBIC) for instance, the lag order selection results in Table 6 indicate an optimum lag-length of one (1) to include in the Cointegration test. Therefore, the study includes one lag in the Cointegration test between variables: “LOGGDP”, “LOGEC” and “LOGKF”.

The Cointegration test results summarized in Table 7 indicate a maximum rank of one. Therefore, we reject the null hypothesis of zero cointegrating vectors in favor of r > 0 by the trace statistic. The trace statistic in Table 7 further indicates that we cannot reject the null hypothesis of one cointegrating vector in favour of r >1. In conclusion, the Cointegration test results indicate presence of one cointegrating vector in the relationship being studied. The implication of the above Cointegration test results is that some linear combination of the variables being tested is stationary even though each variable is not stationary in levels, that is to say, at most some pair of variables being tested trend together in the log-run.

4.5 Regression Estimates of the Vector Error Correction Model (VECM)

Having established evidence of Cointegration in the empirical model, the study establishes the short-run and the long-run causality by estimating a VECM. We based the implementation of VECM on the maximum likelihood framework of [61,62]. Table 8 gives a summary of VECM estimates and Table 9 gives a summary of the estimated cointegrating vector.

The most important estimates relate to the first two equations in the VECM estimates summarized in Table 8. In the first equation where " $\Delta LOGGDP_t$ " is left hand endogenous variable, the estimates show that the first lagged error term is negative and statistically significant (as expected) at 1 percent level of significance. This indicates that Uganda's economic growth converges to its log-run equilibrium value from short run disequilibrium. It also indicates that the first equation is dynamically stable. In the first equation, estimates indicate that the first two differenced lags of "LOGGDP", the third first differenced lag of "LOGEC", the first two differenced lags of "LOGGCF" and the constant term are all statistically significant at 5 percent level of significance. These results suggest that electricity consumption expenditure on electricity positively granger causes economic growth at the third lag. That is to say, it takes approximately three years for positive causality to flow or run from electricity consumption expenditure on electricity to economic growth.

Table 8. The VECM estimates of the empirical model

Equation	Variables	Coef	Std. Err	p-value
$\Delta LOGGDP_t$	ECT_{t-1}	-1.4441***	0.32485	0.000
	$\Delta LOGGDP_{t-1}$	0.9180***	0.27076	0.001
	$\Delta LOGGDP_{t-2}$	0.8210***	0.30854	0.008
	$\Delta LOGGDP_{t-3}$	0.2333	0.34841	0.503
	$\Delta LOGEC_{t-1}$	0.0915*	0.04792	0.056
	$\Delta LOGEC_{t-2}$	0.0574	0.04082	0.160
	$\Delta LOGEC_{t-3}$	0.1173***	0.04321	0.007
	$\Delta LOGKF_{t-1}$	-0.7941***	0.30220	0.009
	$\Delta LOGKF_{t-2}$	-0.4825***	0.27977	0.085
	$\Delta LOGKF_{t-3}$	-0.1351*	0.31646	0.669
	$Const$	0.1219***	0.03609	0.001
$\Delta LOGEC_t$	ECT_{t-1}	1.3937	1.50201	0.353
	$\Delta LOGGDP_{t-1}$	-2.2378*	1.25189	0.074
	$\Delta LOGGDP_{t-2}$	-2.7031*	1.42658	0.058
	$\Delta LOGGDP_{t-3}$	0.4727	1.61097	0.769
	$\Delta LOGEC_{t-1}$	0.1620	0.22158	0.464
	$\Delta LOGEC_{t-2}$	-0.2593	0.18875	0.170
	$\Delta LOGEC_{t-3}$	-0.1160	0.19975	0.561
	$\Delta LOGKF_{t-1}$	1.6165	1.39728	0.247
	$\Delta LOGKF_{t-2}$	2.9041**	1.29356	0.025
	$\Delta LOGKF_{t-3}$	-1.3867	1.46318	0.343
	$Const$	0.1873	0.16685	0.262
$\Delta LOGKF_t$	ECT_{t-1}	-0.9422**	0.38441	0.014
	$\Delta LOGGDP_{t-1}$	0.9773***	0.3204	0.002
	$\Delta LOGGDP_{t-2}$	0.7171**	0.3651	0.050
	$\Delta LOGGDP_{t-3}$	0.0961	0.4123	0.816
	$\Delta LOGEC_{t-1}$	0.0873	0.05671	0.124
	$\Delta LOGEC_{t-2}$	0.0720	0.04831	0.136
	$\Delta LOGEC_{t-3}$	0.1258**	0.05112	0.014
	$\Delta LOGKF_{t-1}$	-0.7426**	0.35760	0.038
	$\Delta LOGKF_{t-2}$	-0.3771	0.33106	0.255
	$\Delta LOGKF_{t-3}$	-0.1124	0.37447	0.764
	$Const$	0.0902**	0.042701	0.035

Source: *Compiled by the author*

, **, * indicate significance at 10%, 5% and 1% respectively*

Table 9. Summary Estimates of the Cointegrating Vector

Equation		Parms	Chi-square	p-value
ECT_{t-1}		2	2789.137***	0.000
		Johansen normalization restriction imposed		
Beta	**Variable**	**Coef**	**Std. Err**	**p-value**
ECT_{t-1}	LOGGDP	1	-	-
	LOGEC	-0.0099	0.02211	0.654
	LOGKF	-0.7484***	0.04211	0.000
	Const.	-6.7667	-	-

Source: *Generated by the author*
**** indicate significance at 1% level*

In the second equation where "ΔLOGEC" is left hand endogenous variable, the VECM estimates in Table 8 show that the first lagged error term is positive (as expected) and statistically insignificant at 5 percent level of significance, suggesting lack of evidence of convergence of consumption expenditure on electricity to its long run equilibrium level. In the same equation, the estimates indicate that all the coefficients on the first three differenced lags on GDP are statistically insignificant at 5 percent level of significance. This suggests that changes in Uganda's economic growth do not have ability to granger cause consumption expenditure on electricity. Thus, results indicate lack of evidence of causality running from economic growth to electricity consumption.

In the second equation where "ΔLOGKF" is left hand endogenous variable, the VECM estimates in Table 8 indicate that the coefficient on the first lagged error correction term is negative and statistically significant at 5 percent level of significance, suggesting that Uganda's gross fixed capital formation converges to its long run equilibrium level. In this equation, the first two differenced lagged differences on "LOGGDP" are positive and statistically significant at 5 percent level. In the same equation, estimates indicate that the coefficient on the third differenced lag on "LOGEC" is positive and statistically significant at 5 percent level and the coefficient on the first differenced lag on "LOGKF" is negative and statistically significant at 5 percent level. These results suggest that positive causality runs from the first two differenced lags of GDP as well as from the third differenced lag of electricity consumption expenditure to gross fixed capital formation, while negative causality runs from the first lagged difference of gross fixed capital formation to itself. Researchers noted that, the VECM estimates show three key results: (i) Uganda's economic growth and gross fixed capital formation converge to their respective long run equilibrium levels (ii) It takes approximately three years for consumption expenditure on electricity to have a positive granger causality on economic growth (iii) Uganda's economic growth does not granger cause consumption expenditure on electricity.

In Table 9, the chi-square statistic produced on the lagged error correction term is statistically significant at 1 percent level. In addition, the estimated cointegrating vector is normalized with a coefficient of unity on "LOGGDP". The estimated coefficient on "LOGEC" is -0.0099 and is statistically insignificant at 5 percent level while the estimated coefficient on "LOGKF" is -0.7484 and is statistically significant at 1 percent level. The implication of the estimates in Table 9 is as follows: the significance of the lagged error correction term and the significant coefficient estimated on "LOGKF" in the cointegrating vector indicates that a VAR in first differences of the variables: "LOGGDP" and "LOGKF" would yield inconsistent estimates due to misspecification. Thus, a VECM is more preferred because it yields consistent estimates.

4.6 Post Estimation Diagnostics

After VECM estimation, we perform two key post estimation diagnostics, namely: (i) we evaluate the predictability of cointegrating equation to see if it predicts the in-sample values adequately, (ii) we evaluate the stability of the estimated VECM.

4.6.1 Evaluating the predictability of the cointegrating equation

For the estimated cointegrating equation to have adequate predictability power, the graph of its predicted in-sample values should be relatively stable (the graph shows some evidence of stationarity). Fig. 4 shows the predicted in-sample values by the cointegrating equation after VECM.

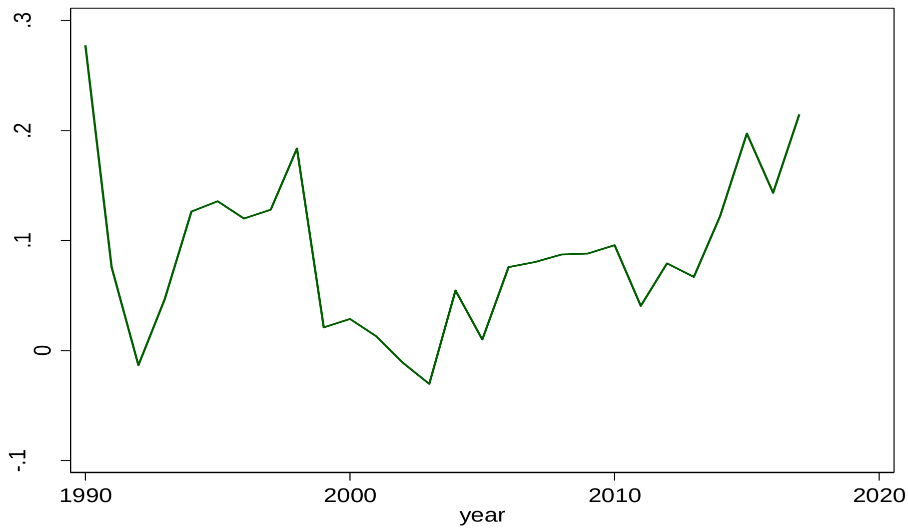

Fig. 4. In-sample values of the cointegrating equation after VECM

Table 10. Companion Matrix Showing Eigen Values After VECM

Eigenvalue	Modulus
1	1
1	1
.4969018 + .2804304*i*	.570572
.4969018 − .2804304*i*	.570572
.1941944	.194194
−.112264	.112264

***Source**: generated by the Author from STATA*

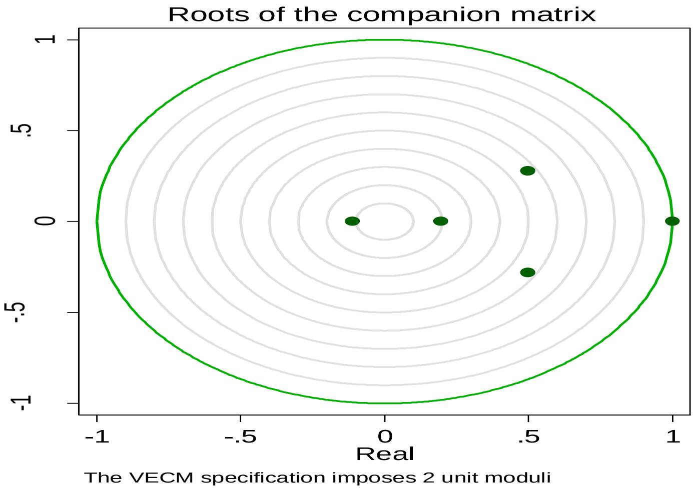

Fig. 5. Roots of the Companion Matrix after VECM

Fig. 4 shows some evidence of stability in the predicted in-sample values. This suggests that the cointegrating equation from VECM adequately predicts the in-sample values.

4.6.2 evaluating the stability of the cointegrating equation

For a K-variable model with *r* cointegrating relationships, the companion matrix will have (*K* - *r*) unit eigenvalues. For the stability, condition to be fulfilled the moduli of the remaining *r* eigenvalues should be strictly less than unity and the roots of the companion matrix should be within the unit circle. In this paper, we have K = 3 variables and *r* = 1 cointegrating relationships. This means the companion matrix will have (*K* - *r*) = (*3* - *1*) = 2 unit eigenvalues, and for stability condition to hold, the remaining *r* eigenvalues should be strictly less than unity and the roots of the companion matrix should be within the unit circle.

Basing on the results in Table 10 and Fig. 5, the stability condition of the VECM is fulfilled. Therefore, the estimated VECM is stable.

5. CONCLUSION AND POLICY IMPLICATIONS

The purpose of this research was to investigate the causality between electricity consumption expenditure and economic growth in Uganda. Time series data spanning from 1986-2017 was used in the study. We conducted stationarity test to investigate the series behavior and conducted Cointegration tests to investigate the existence of long run relationships. Researchers estimated the underlying model in a VECM framework. Results indicate that, all the model variables are integrated of order one. The Cointegration test detected existence of Cointegration between economic growth, consumption expenditure and gross fixed capital formation. Diagnostic tests indicated strong in-sample predictability and stability of the estimated VECM. Results from VECM estimates indicate that it takes approximately three years for causality to run from consumption expenditure on electricity to economic growth and that Uganda's economic growth does not granger cause consumption expenditure on electricity. The key policy implication derived from the study results is that although electricity consumption does not benefit from economy expansion; the results support reforms in the electricity sub-sector that create incentives for increased electricity consumption expenditure among the end users. This policy reform does not only increase the welfare of the end users from electricity consumption but also will have a net positive impact of economic growth.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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