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Electricity Consumption-Economic Growth Linkage: Revisited Evidence From Uganda

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This study examines the economic growth-electricity linkage in Uganda while controlling for some major determinants of economic growth by employing quarterly data from 2008Q1-2021Q3 using the Auto Regressive Distributed Lag (ARDL) approach. We find evidence for the feedback hypothesis implying that Uganda's economic growth and electricity consumption influence each other. Therefore, the paper recommends that Uganda establish and enforce policies that promote the efficient use of electricity, thus promoting sustainable economic growth. It should also increase electrification in the country to boost the economy. Notably, the government should explore solar energy and other energy sources to complement hydroelectricity, thus enhancing economic growth.

Keywords: cointegration, ARDL Model, energy efficiency

Introduction

Electricity is vital in economic development since it is essential for industrial development, household purposes (cooking, lighting, washing, heating, etc.), medical uses, education sector, communication sector, transportation, entertainment, conservation of energy and nature, etc. Thus it leads to economic growth and social welfare. Hence, energy (electricity) constraints negatively affect economic growth. Uganda has one of the world's lowest electricity consumption per capita (215 kWh per capita) (Energypedia, 2021). Despite the low electricity consumption level, but gradually increasing, Uganda has had a positive annual GDP growth rate since 1986, with an average GDP annual growth of 6.18% from 1986 to 2020 (Statistics-Times, 2021). Moreover, the literature presents controversial findings regarding the electricity-economic growth nexus; hence Ozturk (2010) postulates that the contradicting results in the literature may be due to differences in country contexts, data quality, and econometric methods used. Moreover, Uganda's 2040 vision is to increase generation capacity to 41,738 MW by 20240, thus increasing its electricity per capita consumption to 3,668 kWh (Nuclear Business Platform, 2021).

Recently the big concern with global warming, the issue of greenhouse gas emissions, and concerns about its effects are increasing, making this study topic of more interest to policymakers. Therefore, policymakers must clearly understand the nexus between energy consumption and economic growth while implementing energy policies. The motivations of this study are based on: (1) Economic growth and energy use nexus is important; (2)

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international literature shows different linkages; (3) Uganda studies are not agreeing on the linkage; (4) we have more recent data, longer time series and "better" tools/models.

This paper addresses the question of whether electricity consumption affects economic growth in Uganda using the Auto Regressive Distributed Lag (ARDL) technique using quarterly data from 2008Q1-2021Q3 while controlling for the major determinants of economic growth in Uganda. The ARDL method is the most appropriate in our study since some of the variables used are integrated of order zero I(0) while others are integrated of order one, I(1). There exists vast literature examining the electricity consumption-economic growth nexus but with mixed findings. For example, some studies (Gurgul & Lach, 2012; Polemis & Dagoumas, 2013) find evidence for the feedback hypothesis of bidirectional causality between energy consumption and economic growth. In contrast, other researchers (Iyke, 2015; Churchill & Ivanovski, 2020) report evidence for the growth hypothesis of unidirectional causality from energy consumption to economic growth. In addition, some scholars like Shahbaz and Feridun (2012) find the conservation hypothesis of unidirectional causality from economic growth to energy consumption. In contrast, other scholars (Karanfil & Li, 2015; Yoo & Kwak, 2010) find the neutrality hypothesis of no causal relationship between energy consumption and economic growth.

Though J. Mawejje and D. N. Mawejje (2016) and Sekantsi and Okot (2016) studied electricity consumption and economic growth in the context of Uganda, the researchers got contradicting results. Sekantsi and Okot (2016) found a bidirectional long-run relationship between electricity consumption and economic growth in Uganda in the long-run, whereas, J. Mawejje and D. N. Mawejje (2016) reported that a long-run unidirectional causality runs from electricity consumption to GDP in Uganda. Moreover, both researchers did not control for other major variables that determine economic growth. Yet economists (Barro, 1996; 2003; Steven, Jeffrey, & Jong-Wha, 2001) agree that investment, government consumption, population growth, trade openness, inflation, life expectancy, education, and democracy are major determinants of economic growth. Being specific to Uganda, Sendi, Mayanja, and Nyorekwa (2021) found that investment, government consumption, trade openness, population growth, and inflation are the major determinants of economic growth.

The conflicting results of these two authors could be due to the fact that, they did not control for other major determinants of economic growth in their model. Hence the main problem of these studies is that they suffer from omitted variable bias. Therefore, their results cannot be entirely relied on to make electricity policies that lead to sustainable economic growth in Uganda. Given the conflicting evidence for Uganda, it's essential to re-examine the electricity consumption critically-economic growth nexus, settle this controversy, and formulate electricity-energy policies that will lead to increased and sustainable economic growth in Uganda.

The contribution of this study is threefold: First, this study is an improvement and extension of the previous studies, which focused mainly on the electricity consumption-economic growth relationship but did not account for the other major determinants of economic growth. Second, we examine the short-run and long-run nexus to determine the true type of causal relationship between electricity consumption and economic growth (no direction, unidirectional or bi-directional) to provide policymakers in Uganda with a better understanding of electricity consumption-economic growth linkage based on empirical findings, thus enabling them to make informed decisions that will ensure sustainable economic growth. Lastly, this study uses more recent data, longer time series, and "better" tools/model (the ARDL approach that is still applicable in case of the variable with mixed order of integration, unlike the Vector Error Correction Model (VECM) method).

The rest of the paper is organized as follows: Section 2 reviews the relevant literature, Section 3 presents the data and methodology, and empirical results are discussed in Section 4, whereas Section 5 provides the conclusions and policy implications.

Literature Review

Overview of Economic Growth and Electricity Consumption in Uganda

Figure 1 shows a graphical representation of the trends of economic growth and electricity consumption in Uganda. It is observed that both electricity consumption and economic growth exhibited an upward trend from 2008 to 2021. Could the upward trends in electricity consumption and economic growth in Uganda imply that these two variables have a causal relationship?

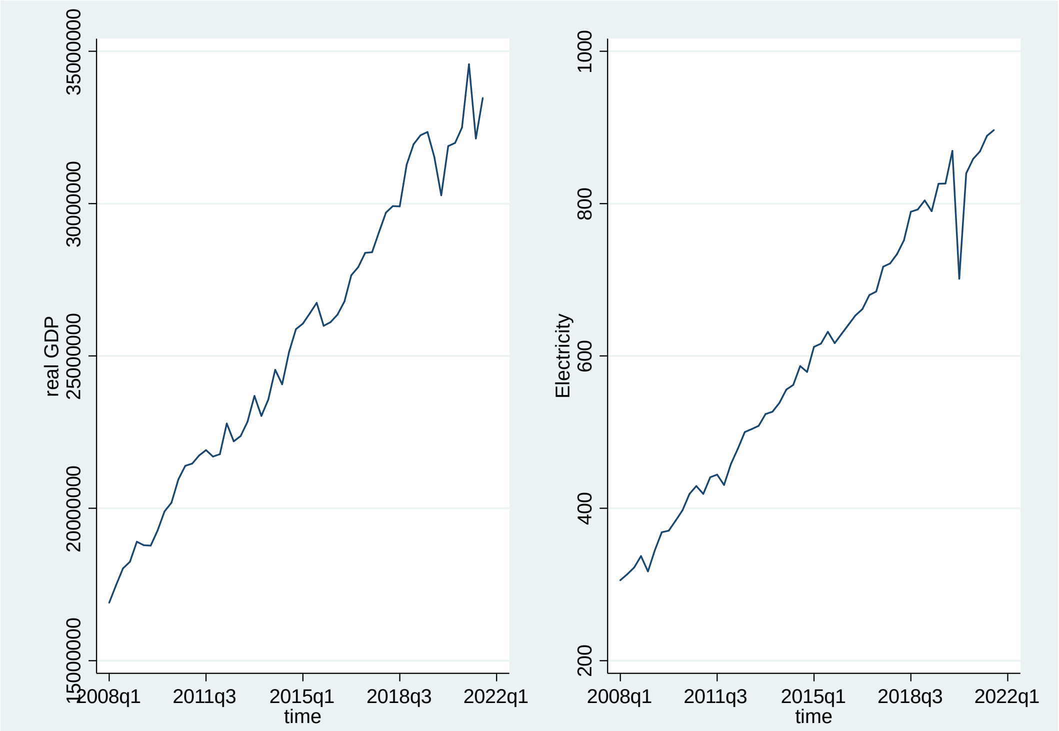

Figure 1. Real GDP in "000000" UGX and electricity consumption in "000000" kWh in Uganda (2008-2022), based on the author's calculations using data from Oxford Economics and Electricity Regulation Authority (ERA) online database.

Focusing on economic growth, a vast literature has investigated the determinant of economic growth in different countries, applying different conceptual and methodological approaches. Robert Solow and Trevor Swan were the first to develop the neoclassical growth model, highlighting the three factors, i.e., labour, capital, and technology as determinants of economic growth. In addition, endogenous growth models state that productivity improvements are influenced by human capital, investment capital, and innovation. Gross capital formation is considered a major determinant of economic growth according to the neoclassical and endogenous growth models, and many empirical studies (Barro, 1995; Barro & Sala-i-Martin, 2004; Fowowe, 2008; Anyanwu, 2014) find evidence for a positive effect of investment on economic growth.

Also, human capital is considered a primary factor affecting economic growth. Many studies find evidence that an educated population positively impacts economic growth (Sala-i-Martin & Barro, 1995; Fayissa & Nsiah, 2010; Barro & Lee, 2013). Further, population growth is essential in the economic growth process, but the relationship between population growth and economic growth is mixed. E.g., Most and De Berg (1996) and Kalemli-Ozcan (2002) reported a negative relationship between population growth and economic growth, whereas Sachs and Warner (1997) and Radelet, Clemens, and Bhavnani, (2004) found that population growth is positively associated with economic growth. Generally, the empirical findings strongly support that inflation harms economic growth (Fischer, 1993; Barro, 1995; Bruno & Easterly, 1998). Moreover, trade openness promotes economic growth (Yavari & Mohseni, 2012; Chirwa & Odhiambo, 2016). Many researchers also consider government consumption as a major determinant of economic growth. Keynesian economists believe consumption expenditure is a dependable function of income, but Barro (1995) and Dobronogov and Iqbal (2007) found that lower government consumption stimulates economic growth. However, Test (2011) found that higher consumption expenditure enhances economic growth in Bangladesh.

In Uganda, Sendi et al. (2021) found that investment, government consumption, trade openness, population growth, and inflation are major determinants of economic growth in Uganda. According to the literature, though the factors above are the major determinants of economic growth, more than 140 variables are proposed as determinants of economic growth (Moral-Benito, 2009). This is due to the fact that the growth theories do not clearly specify the explanatory variables to include in the "true" regression. Therefore, researchers have developed models showing that variables like market distortions, weather, electricity, and institutions, etc., should be included in the growth regression. This paper focuses on the impact of electricity consumption on economic growth in Uganda. Electricity is vital in the economic development of any country since it enhances industrial performance, thus increasing economic growth.

Sekantsi and Okot (2016) and J. Mawejje and D. N. Mawejje (2016) studied the relationship between electricity consumption and economic growth in Uganda. However, they did not control for the major determinants of economic growth in Uganda and thus omitted variable bias, which weakened their results. This study improves and extends the previous studies by controlling for the major determinants of economic growth in Uganda to get robust results.

Review of Recent and Relevant Literature on Electricity Consumption and Economic Growth

There is vast literature investigating the relationship between electricity consumption and economic growth emerging as extensions of the pioneering work of J. Kraft and A. Kraft (1978). They found unidirectional causality from GNP to energy consumption in the United States. Despite the numerous studies on the electricity consumption-economic growth relationship, there is no consensus on the results. However, four types of relationships between electricity consumption and economic growth can be identified: (i) electricity consumption-led growth (growth hypothesis), (ii) feedback hypothesis (bi-directional causality), (iii) growth-led electricity consumption hypothesis (conservation hypothesis); and (iv) the neutrality hypothesis (no causality). Below we present empirical evidence for each hypothesis.

Focusing on the evidence of the growth hypothesis of electricity consumption, Lawal, Ozturk, Olanipekun, and Asaleye (2020) examined the electricity consumption-economic growth nexus in 17 Sub-Saharan African countries using data from 1971 to 2017 employing the System GMM technique. The researchers also control for the other determinants of economic growth, such as financial development, foreign direct investment, trade, government spending, life expectancy, education, inflation, labour, saving rate, and governance effectiveness. The argument is that electricity consumption and other control variables jointly determine economic growth. Their results support the evidence of the growth hypothesis, implying that electricity consumption has a positive unidirectional effect on economic growth. However, upon further examination, while considering the threshold effect, these authors found that electricity consumption has a positive marginal effect on economic growth only in periods of low energy intensity. Still, electricity consumption has a negative marginal effect on economic growth in periods of high energy intensity. The threshold value of the energy intensity was 0.48. This indicates high energy intensity leads to a waste of energy, negatively impacting economic growth. Overall, on the one hand, policies that stimulate electricity consumption should be promoted to enhance economic growth and sustainable growth on the other hand by ensuring that electricity consumption which is not beyond the threshold value.

Similarly, Churchill and Ivanovski (2020) found that electricity consumption at the state level is positively related to economic growth in Australia. The study uses panel data from 1990 to 2015 and controls for labour and capital. Moreover, Iyke (2015) found a positive unidirectional relationship from electricity consumption to economic growth in Nigeria using the Vector Error Correction Model (VECM) and employing data covering a period from 1971 to 2011. The study controls for inflation. Likewise, Yoo and Kwak (2010) found a positive unidirectional causality from electricity consumption to economic growth in Argentina, Brazil, Chile, Columbia, and Ecuador using the Granger causality technique and data for 1975-2006. These studies suggest that such economies should enhance the generation and consumption of electricity to boost economic growth. Also, adopting energy conservation policies should be avoided as they will negatively impact economic growth.

Concerning the bi-directional hypothesis of electricity consumption-economic growth theory, Polemis and Dagoumas (2013) conducted a study in Greece using data from 1970 to 2011, employing the cointegration technique and the Vector Error Correction Model and controlling for other variables such as employment and electricity price in their model. The researchers' results revealed evidence for a bi-directional causality between electricity consumption and economic growth. Similar findings of bi-directional causality were reported in Poland in a study by Kasperowicz (2014). This author obtained results indicating a bi-directional causality between electricity consumption and economic growth in Poland using 2000-2012 data, employing the Granger causality technique and Ordinary Least Squares (OLS) model estimations and controlling for capital and employment. Also, Hamdi, Sbia, and Shahbaz (2014) found bi-directional causality between electricity consumption and economic growth in Bahrain. Their study used quarterly data from 1980 to 2010, applying the ARDL technique and Granger causality approach while controlling for capital and foreign direct investment.

In addition, Osman, Gachino, and Hoque (2016) explored the electricity consumption-economic growth relationship in the GCC countries using data from 1975 to 2012. They employed the Panel VAR Granger causality test, controlled for gross capital formation and obtained support for the feedback hypothesis. Furthermore, Ogundipe and Apata (2013) found support for the feedback hypothesis in Nigeria. Their study used the Vector Error Correction Model (VECM) and Granger causality technique and data covering the period of 1980 to 2008 while controlling for labour and capital. Even the results of Karanfil and Li (2015) revealed a bi-directional causality between electricity consumption and economic growth in the long run. Their study uses a panel data approach based on a sample of 160 countries and classified as developed according to geographical location and income. They used data for the period of 1980-2010 and accounted for the degree of electricity dependence and the level of urbanization.

Additionally, in Pakistan, Shahbaz and Lean (2012) found evidence for the feedback hypothesis after controlling for the major production factors (capital and labour). The authors use the ARDL and VECM Granger causality techniques using 1972 to 2009 data. The study also accounts for electricity trade and urbanization in their model. Also, Bayar and Özel (2014) documented a bi-directional causality between electricity consumption and economic growth in selected emerging economies using the VAR Granger causality technique and data covering the period of 1970 to 2011. Further, Gurgul and Lach (2012) documented evidence for the feedback theory between electricity consumption and economic growth in Poland. They used quarterly data from 2000 to 2009, employed the VECM approach and controlled for employment. Likewise, Yoo and Kwak (2010) found a bi-directional causality between electricity consumption and economic growth in Venezuela using the Granger causality technique and data for 1975-2006. These studies suggest that such countries should explore and exploit new energy sources to achieve sustainable economic growth in the long run.

Regarding the conservation theory of electricity consumption, Shahbaz and Feridun's (2012) results showed a positive unidirectional relationship from economic growth to electricity consumption in Pakistan. This study used the ARDL method using 1971-2008 data. Similarly, Karanfil and Li (2015) found support for conservation theory in the short-run in the Middle East, Pacific, East Asia, North Africa, and Lower-Middle income sub-samples. This implies that in the short-run economic growth leads to increased electricity consumption; hence energy conservation policies will not harm economic growth in the short-run.

Considering the neutrality hypothesis of electricity consumption, Karanfil and Li (2015) found evidence for this theory in their empirical panel data study. The researchers found no relationship between electricity consumption and economic growth in the short-run in their North America, Sub-Saharan Africa, and Upper-Middle income sub-samples. Likewise, Yoo and Kwak (2010) found no relationship between electricity consumption and economic growth in Peru using the Granger causality technique for a period from 1975 to 2006.

Being specific to Uganda, the literature on the electricity consumption-economic growth nexus is limited. The two studies in this area find contradictory results. In the long-run, Sekantsi and Okot (2016) found a bi-direction causality between electricity consumption and economic growth in Uganda, confirming the feedback theory. The study used data from 1982 to 2013 and employed the ARDL technique and Granger causality tests. However, J. Mawejje and D. N. Mawejje (2016) documented evidence of the growth hypothesis in Uganda, indicating a unidirectional causality from electricity consumption to economic growth. This research used the VECM approach and quarterly data from 2005 to 2015. The different results will have different policy implications. The difference in these authors' results may be mainly because they do not control for other significant determinants of economic growth in Uganda and thus omitted variable bias, which weakens their results. Sendi et al. (2021) found that investment, government consumption, trade openness, population growth, and inflation are major determinants of Uganda's economic growth. Therefore, this study improves and extends the previous studies by controlling for the major determinants of economic growth in Uganda to get robust results.

Table 1

Summary of Recent and Relevant Literature on Electricity Consumption and Economic Growth

Authors	Control variables	Research method	Findings	Study period	Context
Lawal et al. (2020)	Financial development, foreign direct investment, trade, government spending, life expectancy, education, inflation, labour, saving rate, and governance effectiveness	System GMM technique	Growth hypothesis	1971-2017	17-Sub-Saharan Africa
Churchill and Ivanovski (2020)	Labour and capital	Panel data technique	Growth hypothesis	1990-2015	Australia
Iyke (2015)	Inflation	Vector Error Correction Model (VECM)	Growth hypothesis	1971-2011	Nigeria

Table 1 to be continued

Yoo and Kwak (2010)	None	Granger causality technique	Growth hypothesis	1975-2006	Argentina, Brazil, Chile, Columbia and Ecuador
Mawejje and Mawejje (2016)	None	VECM approach	Growth hypothesis	2005-2015	Uganda
Polemis and Dagoumas (2013)	Employment and electricity price	Vector Error Correction Model (VECM)	Feedback hypothesis	1970-2011	Greece
Kasperowicz (2014)	Capital and employment	Granger causality technique and Ordinary Least Squares (OLS)	Feedback hypothesis	2000-2012	Poland
Hamdi et al. (2014)	Capital and foreign direct investment	ARDL technique and Granger causality approach	Feedback hypothesis	1980-2010	Bahrain
Osman et al. (2016)	Gross fixed capital formation	Panel VAR Granger causality test	Feedback hypothesis	1975-2012	GCC countries
Ogundipe and Apata (2013)	Labour and capital	Vector Error Correction Model (VECM)	Feedback hypothesis	1980-2008	Nigeria
Karanfil and Li (2015)	Degree of electricity dependence and the level of urbanization.	Panel data technique	Feedback hypothesis	1980-2010	160 countries
Shahbaz and Lean (2012)	Labour, capital, electricity trade, and urbanization	ARDL and VECM Granger causality techniques	Feedback hypothesis	1972-2009	Pakistan
Bayar and Özel (2014)	None	VAR Granger causality technique	Feedback hypothesis	1970-2011	Brazil, Chile, China, Colombia, Czech Republic, Egypt, Greece, Hungary, India, Indonesia, Korea, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Taiwan, Thailand, and Turkey
Gurgul and Lach (2012)	Employment	VECM approach	Feedback hypothesis	2000-2009	Poland
Yoo and Kwak (2010)	None	Granger causality technique	Feedback hypothesis	1975-2006	Venezuela
Sekantsi and Okot (2016)	None	ARDL method and Granger causality technique	Feedback hypothesis	1982-2013	Uganda
Shahbaz and Feridun (2012)	None	ARDL method	Conservation hypothesis	1971- 2008	Pakistan
Karanfil and Li (2015)	Degree of electricity dependence and the level of urbanization	Panel data technique	Conservation hypothesis	1980-2010	Middle East, Pacific, East Asia, North Africa, and Lower-Middle income sub-samples
Karanfil and Li (2015)	Degree of electricity dependence and the level of urbanization	Panel data technique	Neutrality hypothesis	1980-2010	North America, Sub-Saharan Africa, and Upper-Middle income sub-samples
Yoo and Kwak (2010)	None	Granger causality technique	Neutrality hypothesis	1975-2006	Peru

From Table 1, it is clear that there are contradicting findings in the literature. The results vary depending on country contexts, period of study, data, and econometric methods. Using the same econometric method does not imply that studies will reach a similar conclusion on the electricity consumption-economic growth nexus.

Therefore, the results depend on many factors not only limited to country contexts and econometric methods but also on the control variables included in the model, the study period, data, and the data frequency.

Research Methodology and Data

All the data used in the empirical estimation are quarterly series obtained from Oxford Economics except for the electricity consumption (Ele) data obtained from the Electricity Regulatory Authority online databases. The data cover the period 2008 Q1-2021 Q3. This gives us 55 observations. In particular, electricity consumption (Ele) is measured in kWh, and economic growth (GDP) is measured as constant or real GDP. Importantly, it is universally acknowledged that economic growth is driven by various factors (Moral-Benito, 2009). Therefore, following Sendi et al. (2021), other variables are added as control variables in the growth Model of Uganda. These are:

- Government consumption is measured as a ratio of general government consumption to GDP. According to Barro (1995), the ratio of government consumption to GDP is intended to measure a set of public outlays that do not directly enhance an economy's productivity. The researcher empirically documents a negative and statistically significant effect of government consumption on GDP.
- Trade openness is measured as total foreign trade relative to GDP, and this is used to capture the degree of international openness. A positive coefficient is expected since increased international openness leads to increased economic activity, thereby boosting economic growth.
- Inflation level is measured as the percentage change in the quarterly consumer price index. Inflation negatively affects GDP since it makes economic planning hard. Thus, a negative coefficient is expected.
- Population growth is measured as the percentage change in the total quarterly population. Since labour is a factor of production, an increase in the labour force due to an increase in population leads to an increase in GDP.

The econometric model is specified as follows:

$$GDP_t = \alpha + \beta_1 Ele_t + \beta_2 Inf_t + \beta_4 Trade_t + \beta_5 Pop_t + \beta_3 Gov'{t}_t + \varepsilon_t \tag{1}$$

where GDP is real GDP, a measure of economic growth, and Ele is electricity consumption measured in kWh. Gov't is government consumption, Trade is trade openness, Pop is population growth, Inf is inflation.

This paper uses the ARDL bounds testing approach by Pesaran, Shin, and Smith (2001) to examine the short-run and long-run relationships between electricity consumption and economic growth in Uganda. In case some variables are stationary at I(0) and others are integrated of order I(1), the Johansen cointegration test cannot be applied directly, but the ARDL model is applicable for variables with different orders of integration (Shrestha & Bhatta, 2018). Further, the ARDL model produces robust results even in small samples. The method provides unbiased estimates of the long-run model and valid t-statistics even in the presence of endogenous regressors. The ARDL model captures both the short-run and long-run effects of the independent variables on the dependent variable. The ARDL model is illustrated as follows:

$$\begin{aligned}\Delta GDP_t = \beta_0 &+ \sum_{i=1}^{n} \beta_{1i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \beta_{2i} \Delta Ele_{t-i} + \sum_{i=1}^{n} \beta_{3i} \Delta Inf_{t-i} + \sum_{i=1}^{n} \beta_{4i} \Delta Gov'{t}_{t-i} \\ &+ \sum_{i=1}^{n} \beta_{5i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \beta_{6i} \Delta Pop_{t-i} + \beta_7 GPP_{t-1} + \beta_8 Ele_{t-1} + \beta_9 Inf_{t-1} \\ &+ \beta_{10} Gov'{t}_{t-1} + \beta_{11} Trade_{t-1} + \beta_{12} Pop_{t-1} + \varepsilon_t\end{aligned} \tag{2}$$

$$\Delta Ele_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta Ele_{t-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \alpha_{3i} \Delta Inf_{t-i} + \sum_{i=1}^{n} \alpha_{4i} \Delta Gov't_{t-i} + \sum_{i=1}^{n} \alpha_{5i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \alpha_{6i} \Delta Pop_{t-i} + \alpha_7 GPP_{t-1} + \alpha_8 Ele_{t-1} + \alpha_9 Inf_{t-1} + \alpha_{10} Gov't_{t-1} + \alpha_{11} Trade_{t-1} + \alpha_{12} Pop_{t-1} + \varepsilon_t \quad (3)$$

Considering Equation (2) Δ is the difference operator. In the first part of the equation $\beta_{1i} \ldots. \beta_{6i}$ represents short-run dynamics of the model, and the second part $\beta_7 \ldots. \beta_{12}$ represents long-run relationships. We conduct the ARDL bound test to check for the existence of cointegration. The null hypothesis (H_0) in the equation is $\beta_7 = \beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = 0$, which means the non-existence of a long-run relationship. If the F-statistics is greater than the Upper Critical Bound (UCB), we reject the H_0, hence cointegration. However, if the F-statistics is less than the Lower Critical Bound (LCB), accept the null of no cointegration. But if $LCB \leq \mathrm{F} - \mathrm{statistics} \leq$ UCB, then the decision is inconclusive.

In this paper, the Akaike Information Criterion (AIC) is used to select the lag length. After finding the long-run relationship between variables, the study uses the Error Correction Model (ECM) to find the short-run dynamics. The Error Correction Model (ECM) for the estimation of the short-run relationships is formulated as:

$$\Delta GDP_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \beta_{2i} \Delta Ele_{t-i} + \sum_{i=1}^{n} \beta_{3i} \Delta Inf_{t-i} + \sum_{i=1}^{n} \beta_{4i} \Delta Gov't_{t-i} + \sum_{i=1}^{n} \beta_{5i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \beta_{6i} \Delta Pop_{t-i} + \varphi_1 ECT_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta Ele_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta Ele_{t-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \alpha_{3i} \Delta Inf_{t-i} + \sum_{i=1}^{n} \alpha_{4i} \Delta Gov't_{t-i} + \sum_{i=1}^{n} \alpha_{5i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \alpha_{6i} \Delta Pop_{t-i} + \varphi_2 ECT_{t-1} + \varepsilon_t \quad (5)$$

where φ is the coefficient of the Error Correction Term (ECT_{t-1}) and it must be negative and statistically significant, indicating that any long-run disequilibrium among the dependent and independent variables will converge back to the long-term equilibrium. It shows the speed of adjustment towards long-run equilibrium.

In case of no cointegration among variables, estimate the ARDL short-run model as follows:

$$\Delta GDP_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \beta_{2i} \Delta Ele_{t-i} + \sum_{i=1}^{n} \beta_{3i} \Delta Inf_{t-i} + \sum_{i=1}^{n} \beta_{4i} \Delta Gov't_{t-i} + \sum_{i=1}^{n} \beta_{5i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \beta_{6i} \Delta Pop_{t-i} + \varepsilon_t \quad (6)$$

$$\Delta Ele_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta Ele_{t-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \alpha_{3i} \Delta Inf_{t-i} + \sum_{i=1}^{n} \alpha_{4i} \Delta Gov't_{t-i} + \sum_{i=1}^{n} \alpha_{5i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \alpha_{6i} \Delta Pop_{t-i} + \varepsilon_t \quad (7)$$

This estimates the short-run dynamics.

To check the robustness of the ARDL model, we apply diagnostic tests for normality of the error term, serial correlation, autoregressive conditional heteroscedasticity, and white heteroskedasticity. The CUSUMSQ test checks for the stability of the long-run and short-run estimates.

Empirical Results and Analysis

The descriptive statistics of the data used in the study and the results are reported in Table 2. The correlation matrix between the variables is reported in Table 3. The section also provides the results from estimating the equations presented in the methodology section, and the results are presented in Tables 4-6. The section also analyses and discusses the findings from the econometric estimations.

Descriptive Statics

On average, the inflation was 6.9% and the population grew at a rate of 0.8% per quarter, during the study period. Electricity consumption in the country was on average 590,000,000 kWh per quarter.

Table 2

Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Real GDP (UGX) “000000”	55	2,5437,831	4,887,473	16,902,000	34,576,000
Inflation (%)	55	6.9	6.16	1.56	28.82
Trade % of GDP	55	14.4	1.43	11.45	17.46
Population growth (%)	54	0.8	0.07	0.67	0.972
Gov’t consumption % of GDP	55	8.8	2.25	6.23	15.97
Electricity consumption (kWh) “000000”	55	590.3	177.48	305.54	896.51

Table 3

Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) GDP	1.000					
(2) Inflation	-0.616	1.000				
(3) Trade openness	0.304	-0.031	1.000			
(4) Gov’t consumption	0.073	-0.242	-0.070	1.000		
(5) Electricity consumption	0.986	-0.628	0.347	0.051	1.000	
(6) Population growth	0.192	-0.237	-0.249	-0.277	0.190	1.000

From Table 3, we observe a positive correlation (0.986) between economic growth and electricity consumption. This means that, when electricity consumption increases by a unit, real GDP increases by UGX 986,000 ($261.1). We note that correlation does not necessarily mean causation and so we test for cointegration in this paper. We observe a negative correlation (-0.616) between economic growth and inflation as expected from literature. We also observe a positive correlation between economic growth and trade openness (0.304). There exists a positive correlation between economic growth and government consumption (0.073).

Unit Root Test

Table 4

Unit Root Test

	Phillips-Perron unit root test				Order of integration
	Intercept		Trend and intercept		
	Level	First difference	Level	First difference	
Variables	p-value	p-value	p-value	p-value	
LnGDP	0.440	0.000***	0.005***	0.000***	I(0)
Inflation	0.136	0.033**	0.087	0.021***	I(1)
Trade openness	0.001***	0.000***	0.003***	0.000***	I(0)
Population growth	0.711	0.000***	0.987	0.000***	I(1)
Gov’t consumption	0.052	0.000***	0.189	0.003***	I(1)
LnElectricity	0.417	0.000***	0.024***	0.000***	I(0)

It is a precondition to establish the order of integration of the variables before applying the ARDL model. The ARDL approach is only applicable if the variable is I(0) or I(1) but not I(2). If any variable is I(2), the F test becomes invalid in deciding the long-run relationship between the variables. This study employs the Phillips-Perron (PP) tests for stationarity, and the results are presented in Table 4. The results revealed that the log of real GDP, trade openness, and Log of electricity consumption are all stationary in level I(0). Note that there is a trend in the series of LnGDP and LnElectricity; hence when interpreting the unit root results for these variables, we use the results where we included a trend and intercept. Inflation, population growth, and government consumption are non-stationary in levels. However, upon taking the first difference, the above variables become stationary. Hence these series are said to be I(1).

Given that in our case, some series are stationary, i.e., I(0), while others are integrated of order one, i.e. I(1), the Johansen cointegration test cannot be applied directly if variables of interest are of mixed order of integration, but the (ARDL) model is applicable for variables with different orders of integration. This model is still not biased if the variables are integrated of the same order. Therefore, we run our estimations using the ARDL approach. An optimal lag length selection is crucial when applying the ARDL bound test since inappropriate lag selection leads to biased results. This study uses the Akaike Information Criterion (AIC) for optimal lag length selection. AIC gives robust results and has excellent performance compared to SC and HQ criteria.

Cointegration Tests

Table 5

ARDL Cointegration Test Results Using the F-Statistic

	(1)	(2)
Variables	(LnGDP, Inflation, Trade openness, Population growth, Gov’t consumption, LnElectricity)	(LnElectricity, LnGDP, Inflation, Trade openness, Population growth, Gov’t consumption)
Optimal lag structure	(2, 3, 1, 3, 2, 3)	(2, 1, 3, 0, 3, 2)
F-statistics	6.34	9.63
Lower bound I(0)	2.62	2.62
Upper bound I(1)	3.79	3.79
Conclusion	Cointegration	Cointegration

Table 5 to be continued

Diagnostics		
R^2	0.70	0.78
Adj-R^2	0.58	0.70
F-statistics	353.81(0.00)	440.27(0.00)
Durbin-Watson statistics	2.01	2.03
Heteroskedasticity	122.90(0.39)	118.35(0.50)
Serial correlation	0.06(0.80)	0.49(0.49)
Jarque-Bera normality test	2.18(0.34)	2.16(0.34)

We carry out cointegration tests between LnGDP and the rest of the variables and between LnElectricity and all the other variables. The results are reported in Table 5. Model 1 corresponds to the equation where LnGDP is the dependent variable, whereas Model 2 reports the results where LnElectricity is the dependent variable.

The above results in Table 5 reveal that there is cointegration in both Models 1 and 2. This is because the F-statistics (6.336 and 9.632) in Models 1 and 2, respectively, are above the critical value for upper bound I(1) (3.79). This implies a long-run relationship between LnGDP and all the other variables and a long-run relationship between LnElectricity and the rest of the variables.

Since there is cointegration in both models, we further estimate the Error Correction Model (ECM); thus, the study reports both long-run and short-run results. These results are presented in Table 6.

Notably, we performed a model stability test through several diagnostic tests, including stability, LM serial correlation, heteroskedasticity, and normality, respectively. The results are shown in Table 4 in the diagnostics panel. The results reveal that the diagnostics of the ARDL model in our study are satisfactory.

Long-Run and Short-Run Analysis

Table 6

Long-Run and Short-Run Analysis

		(1) LnGDP			(2) LnElectricity	
Variables	ECT-1	Long-run	Short-run	ECT-1	Long-run	Short-run
D.logGDP						-0.375
						(0.348)
LD.logGDP			0.028			-0.238
			(0.230)			(0.284)
L2D.logGDP			0.090			
			(0.201)			
D.inflation			-0.002			0.001
			(0.003)			(0.004)
LD.inflation			0.000			-0.001
			(0.002)			(0.003)
L2D.inflation			0.004*			-0.000
			(0.002)			(0.003)
L3D.inflation			-0.002			0.001
			(0.002)			(0.003)
D.trade			-0.006			0.004
			(0.005)			(0.006)

Table 6 to be continued

LD.trade			-0.001			
			(0.004)			
D.population			-0.624**			0.532
			(0.275)			(0.409)
LD.population			-0.264			-1.583***
			(0.447)			(0.535)
L2D.population			-0.419			0.759*
			(0.283)			(0.383)
L3D.population			-0.221			-1.195**
			(0.389)			(0.453)
D.gov’t consumption			-0.003			0.004
			(0.005)			(0.007)
LD.gov’t consumption			0.003			0.008
			(0.007)			(0.009)
L2D.gov’t consumption			-0.000			-0.004
			(0.006)			(0.009)
D.electricity			-0.353*			
			(0.181)			
LD.electricity			-0.230			-0.479**
			(0.184)			(0.217)
L2D.electricity			-0.082			-0.226
			(0.182)			(0.171)
L3D.electricity			-0.146			
			(0.141)			
L.logGDP	-0.692**					
	(0.256)					
L.electricity				-0.466**		
				(0.222)		
Log GDP					1.224***	
					(0.296)	
Inflation		-0.002			-0.003	
		(0.004)			(0.007)	
Trade openness		0.003			0.019	
		(0.008)			(0.014)	
Population growth		0.274			0.558	
		(0.213)			(0.476)	
Gov’t consumption		0.004			-0.008	
		(0.005)			(0.009)	
Electricity		0.506***				
		(0.080)				
Constant			9.374**			-7.034
			(3.355)			(5.110)
Observations	50	50	50	50	50	50
R-squared	0.698	0.698	0.698	0.778	0.778	0.778

Notes. Figures in parentheses are Robust standard errors, ****, **, * stand for statistical significance at 1 per cent, 5 per cent, and 10 per cent levels, respectively.

This study found cointegration between LnGDP and its determinants and Lnelectricity and its determinants at a 5% significance level. Hence, the study has estimated both long-run and short-run equations for these models. The results are reported in Table 6. Regarding the short-run results, economic growth (GDP) is influenced by the second lag of inflation, the current level of population growth, and the current level of electricity consumption only, whereas electricity consumption is only influenced by population growth and the first lag of electricity in the short-run. Our emphasis is on the long-run relationships in Models 1 and 2. The Error Correction Terms (ECT-1) are negative and statistically significant at a 5% significance level in both models. For example, in Model 1, the Error Correction Term has a coefficient of -0.692, implying that the disequilibrium can be adjusted in the long-run at a speed of 69.2% each quarter of the year, whereas in Model 2, the coefficient for Error Correction Term is -0.466, which implies that any disequilibrium will be adjusted in the long-run at a speed of 46.6% per quarter.

Focusing on Model 1 (GDP is the dependent variable), we find that electricity consumption is the only significant determinant of economic growth (GPD) in the long-run. Electricity is positively signed and statistically significant at a 1% significance level. A 1% increase in electricity consumption leads to a 50.6% increase in GDP in the long-run in Uganda. The long-run elasticities for electricity on GDP (50.6%) in this study are almost similar to those of J. Mawejje and D. N. Mawejje (2016), i.e., 60.3%. Note, though insignificant, these other variables are rightly signed. For instance, inflation has a negative coefficient, whereas trade openness, population growth, and government consumption are positive.

Looking at Model 2 (electricity is the dependent variable), the long-run results revealed that the only determinant of electricity consumption, in the long run, is economic growth (GDP). GDP is positive and statistically significant at a 1% level of significance. A percentage increase in real GDP increases electricity consumption by 122.4% in the long-run in Uganda. The long-run results in Models 1 and 2 indicate that Uganda's economic growth and electricity consumption influence each other. The results confirm the feedback hypothesis of bi-directional causality between economic growth and electricity consumption. Our results support Sekantsi and Okot (2016), who found a bi-directional causality between Uganda's economic growth and electricity consumption. However, they contradict the findings of J. Mawejje and D. N. Mawejje (2016), who found a unidirectional causality from electricity to GDP in Uganda. Moreover, similar results to the conclusions of this study (bi-directional causality between GDP and electricity consumption) have been reported by Guttormsen (2007), Yoo and Kwak (2010), Gurgul and Lach (2012), Shahbaz and Lean (2012), Ogundipe and Apata (2013), Polemis and Dagoumas (2013), Bayar and Özel (2014), Hamdi et al. (2014), Kasperowicz (2014), Karanfil and Li (2015), and Osman et al. (2016).

Conclusion

In this study, we examine the relationships between economic growth and electricity consumption while controlling for other major determinants of economic growth (inflation, trade openness, population growth, and government consumption) in Uganda, using quarterly data from 2008Q1 to 2021Q3, and employing the ARDL econometric technique. We find empirical evidence for a long-run bi-directional relationship between economic growth and electricity consumption. This implies that Uganda's economic growth and electricity consumption influence each other. In conclusion, in Uganda, high economic growth leads to increased electricity consumption, and increased electricity consumption leads to higher economic growth. Hence, the policy implications of this study are that Uganda should increase electrification to boost economic growth. Notably, the government should explore other decentralized energy sources, such as solar energy, to supplement electricity supplied through the grid (mainly hydroelectricity), thus enhancing economic growth. Also, Uganda should develop and promote electricity policies that ensure efficient energy use, thus promoting sustainable economic growth.

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