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Electricity consumption and sectoral output in Uganda: an empirical investigation

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Abstract

We examine the causal relationship between electricity consumption and sectoral output growth in Uganda. First, we use vector error correction techniques to estimate the long-run relationship between electricity consumption and GDP growth. Second, we apply Granger causality tests to determine the direction of this relationship. Third, we disaggregate GDP into its major sectors of agriculture, industry and services and test for Granger causality between sectoral output growth and electricity consumption. At the macro-level, results suggest long-run unidirectional causality running from electricity consumption to GDP. At the sectoral level, results indicate long-run causality running from electricity consumption to industry; a unidirectional short-run causality running from services sector to electricity consumption; and neutrality in the agricultural sector. These results have important implications for policy. In particular, policies that improve electricity generation and consumption will accelerate growth in Uganda by facilitating industrial sector growth. Moreover, electricity conservation policies can be applied in the services sector without hurting growth.

Keywords: Electricity consumption, Sectoral output, Uganda

JEL Classification: Q41, Q43

1 Introduction

Energy consumption plays an important role in the growth and development processes as it facilitates production and improves household welfare (Wolde-Rufael 2006; Karekezi 2002). Consequently, there exists a rich and diverse body of literature examining the causal relationship between energy consumption and economic growth (see Payne 2010 for a survey). However, this literature provides diverse results and has not been conclusive, especially on the direction of this relationship. This may be due to differences in country contexts, data quality and econometric methods used (Ozturk 2010).

Uganda presents an interesting case study for the examination of the relationship between electricity consumption and GDP growth. First, the economy has registered impressive growth rates averaging about 7 % over the past two or so decades. However, this has been possible despite a relatively undeveloped energy sector characterised by low levels of electricity generation and consumption (Mawejje et al. 2013). Second, the government is focused on an ambitious programme to expand electricity production leading to improved consumption per capita from 80 kWh in 2015/16 to 3668 kWh in 2040 (GoU 2015).

One possible argument to explain Uganda's growth despite the low levels of electricity consumption could lie in the sectoral composition of the drivers of growth. For two decades, Uganda's growth has been supported by the low energy-intensive services sector (Hausmann et al. 2014). Secondly owing to the large energy deficits in the country, the large manufacturing plants received World Bank support to implement power factor correction technologies which helped to improve energy efficiency and therefore reduced peak electricity demand (Okoboi and Mawejje 2016; World Bank 2012).

Despite the recent developments and renewed Government commitment to expand electricity generation, there is limited empirical work on the relationship between electricity consumption and output growth in Uganda. Earlier micro-founded work by Reinikka and Svensson (2002) suggested that electricity constrained firms may make suboptimal investments—for example in own electricity generation—often at the expense of productive investment. Further, enterprise level surveys indicate that electricity constraints have the biggest drag on firm-level performance and continue to be among the severest constraints that firms have to deal with (World Bank 2013; Mawejje 2013). This evidence is suggestive of the important relationship between electricity consumption and firm growth. However, results from macro-founded research in other developing countries comparable to Uganda have not been conclusive, especially on the direction of causality (Akinlo 2008; Odhiambo 2010).

Against this background, this paper investigates the relationship between electricity consumption and economic growth in Uganda. An important contribution of this paper is the consideration of disaggregated GDP data to examine the sectoral linkages between electricity consumption and output growth in a developing agrarian economy. This paper takes advantage of the recently rebased quarterly GDP figures from the Uganda bureau of Statistics (UBOS) and a new and updated database on electricity consumption from the Electricity Regulatory Authority (ERA).

Our empirical strategy follows two separate but complementary approaches. First, we use vector error correction techniques to estimate the long-run relationship between electricity consumption and GDP growth. Second we apply Granger causality tests to determine the direction of this relationship. In addition, disaggregating GDP into its major sectors of agriculture, industry and services, we test for Granger causality between sectoral output growth and electricity consumption.

Results suggest a long-run unidirectional causal relationship running from electricity consumption to GDP. However, there are significant sectoral differences in this relationship. In particular, we confirm the "growth", "conservation" and "neutrality" hypotheses in the industry, services and agriculture sectors, respectively. These results suggest that current efforts to improve electricity generation will accelerate growth in Uganda by facilitating industrial sector growth. Moreover, results suggest electricity conservation policies can be applied in the services sector without hurting growth.

The rest of the paper is organised as follows: Sect. 2 provides the background; Sect. 3 surveys the literature; Sect. 4 introduces the methods; the data are introduced in Sect. 5; results are discussed in Sec. 6; Sect. 7 provides the conclusions and policy implications.

2 Background

The current poor status of the electricity sector in Uganda partly reflects the effects of extreme neglect owing to political instability and the subsequent economic crises, particularly suffered between 1971 and 1986. During that period, most productive sectors, including the electricity sector, were struggling. Electricity production fell from 150 MW in 1963 to 60 MW in 1987. The economy was characterised by huge energy deficits, and the drive to expand electricity consumption, including in rural areas, was severely affected.

The Uganda Electricity Board (UEB), formally created as a quasi-independent vertically integrated natural monopoly, was the sole player in the electricity sector. The UEB was tasked with the generation, transmission and distribution of electricity within Uganda. The Board also had a vision to export electricity within the East Africa region. Initially, electricity was expanded to major urban centres with a view of making them centres of economic activity. Thus, electricity was initially available in Jinja, Kampala and Entebbe. In the years that followed, the UEB started to expand electricity to other parts of the country. The expectation was that electricity would spur social and economic transformation.

However, in the period that followed, the expected benefits of electrification were not realised because of the huge technical and financial constraints faced by the UEB at the time. The major challenge that faced the UEB was the lack of finances required to expand the grid to the rural areas, with the result that new customer numbers flattened out quickly and that the sector relied heavily on Government subsidies (Mawejje et al. 2013).

Starting in 1987, the Uganda Government embarked on an extensive Economic Recovery Program and policy reforms that mostly prioritised price stabilisation, privatisation and liberalisation. The electricity sector was restructured with a view of making it economically viable (Mawejje et al. 2013). The new Electricity Act was finalised in 1999 and the Energy Policy in 2002. In 2003, the Rural Electrification Board was appointed to oversee the Rural Electrification Trust Fund (RETF) with a view of expediting the process of rural electrification.

The rural electrification strategy was established in 2001. The first Rural Electrification Strategy and Plan (RESP) aimed at increasing access to the national grid from 10 % in 2010 to 20 % in 2015. The strategy is enshrined in the Electricity Act, enacted in 1999. The aim of the first strategy (2000–2010) was to increase rural population access to electricity from 2.4 % in 2000 to 10 % in 2010 which was later changed to 2012. The second Rural Electrification Strategy and Plan (RESP) will cover 10 years from 2013 to 2022. This plan's objective is "to position the electrification development program on a path that will progressively advance towards achievement of universal electrification by the year 2040, consistent with the existing policy of the Government, while ensuring the displacement of kerosene lighting in all rural Ugandan homes by 2030".

In addition, other organs such as the Rural Electrification Agency (REA) and Board (REB) were established "to promote support and provide for rural electrification programs". To date, electricity has been extended to all district headquarters, with the exception of Kotido and Kaabong in the Karamoja Sub-Region. The Rural Electrification Agency (REA) holds the broad mandate of ensuring rural electrification, especially in areas of limited interest to the private sector due to the limited profitability. The REA has divided rural Uganda into twelve electricity distribution service territories and contracted rural electricity distribution companies to operate and maintain the electricity distribution infrastructure and to expand access to electricity in rural communities. The Electricity Regulatory Authority (ERA) on the other hand has prescribed non-cost-reflective (subsidised) tariffs for rural electricity consumers. The REA on its part subsidises the connection costs by meeting some of the costs related to the internal wiring of houses. The overall goal of all this is to increase rural access to electricity from the current 5 to 26 % by 2022.

There is now a renewed focus on the prioritisation of electricity generation, efficiency and rural electrification. Subsequently, the total installed electricity generation capacity has increased from 595 MW in 2010 to 850 MW in 2014. In addition, the total electricity supplied increased from 2737 GWh in 2012 to 2932 GWh in 2013. The growth in overall installed capacity has largely been on account of investments in mini-hydro generation and the completion of the 250 MW plant at Bujagali.

Despite these efforts, the electricity sector remains relatively undeveloped. Only 4.4 % of rural households had access to electricity on the grid in 2014 (Mawejje 2014). As a result, Uganda's electricity consumption, estimated at 80kWh per capita in 2012, is one of the lowest in the whole world. In addition, reliability of electricity supply continues to be a major constraint to private sector competitiveness and growth: one in every four business in Uganda report electricity reliability as the most challenging constraint (World Bank 2013).

At the sectoral level, the industrial sector continues to account for the largest share of electricity consumption in Uganda at 63 %; commercial consumption accounts for 13 % and domestic consumers 25 %—with some variations through time (Fig. 1).

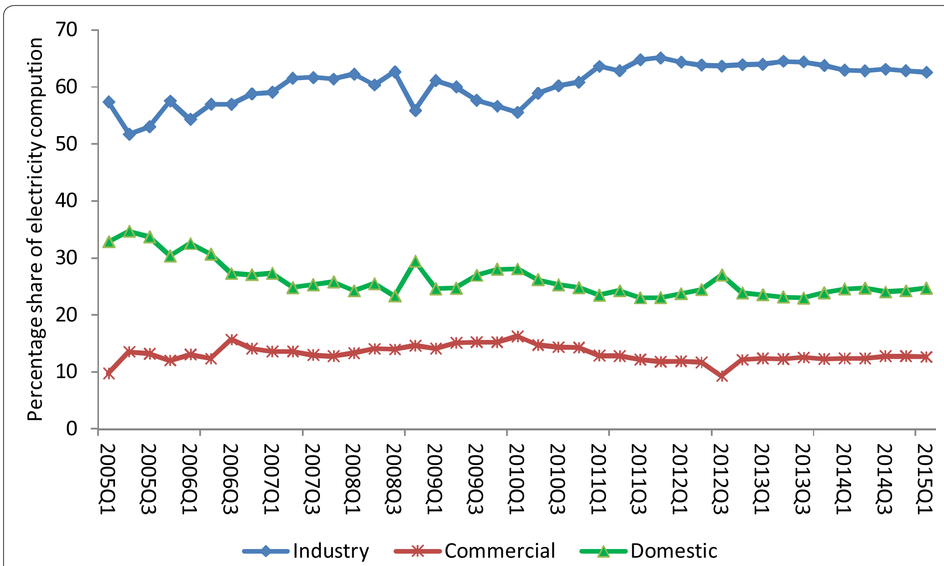

Fig. 1 Electricity consumption shares

3 Literature survey

The literature identifies four hypotheses that describe the types of causal relationships between electricity consumption and economic growth which are summarised here: (1) the neutrality hypothesis; (2) the conservation hypothesis; (3) the growth hypothesis; and (4) the feedback hypothesis. Collectively, these theories explain all possible causal relationships between electricity consumption and economic growth (Ozturk 2010; Payne 2010; Rögnvaldur 2009).

3.1 The neutrality hypothesis

The core proposition of the neutrality hypothesis relates to the absence of causality between energy consumption and economic growth. The empirical confirmation of the neutrality hypothesis is usually interpreted to imply that neither conservation nor expansive policies in relation to electricity consumption have any effect on economic growth. A number of studies have confirmed the neutrality hypothesis. Cheng (1997) used cointegration techniques and the Granger causality tests based on Hsiao techniques to investigate the causal relationship between energy consumption in Brazil, Mexico and Venezuela. The neutrality hypothesis was confirmed for both Venezuela and Mexico. Other studies that have confirmed the neutrality hypothesis include: Halicioglu (2009) who used Granger causality and Autoregressive Distributed Lag (ARDL) techniques on Turkey; Payne (2009) who used Yoda–Yamamoto causality test on USA; Soytas and Sari (2009) who also used Yoda–Yamamoto causality test on Turkey; and Ozturk and Acaravci (2011) who used ARDL bounds testing procedure on 11 Middle East and North Africa (MENA) countries.

3.2 The conservation hypothesis

The conservation hypothesis suggests the presence of unidirectional causality running from economic growth to electricity consumption. In this respect, the empirical confirmation of the conservation hypothesis is usually interpreted to imply that electricity conservation polices may be implemented with minimal effects on economic growth. Within this realm, Odhiambo (2010) used ARDL methods to show that it is economic growth driving energy consumption in the Democratic Republic of Congo (DRC). Other empirical support for the conservation hypothesis in developing countries has been provided by among others Mozumder and Marathe (2007) for Bangladesh; Halicioglu (2007) for Turkey; Hu and Lin (2008) for Taiwan; and Ghosh (2002) for India.

3.3 The growth hypothesis

The growth hypothesis is premised on the presence of unidirectional causality running from electricity consumption to output growth. This relationship suggests that shocks to electricity consumption may adversely affect growth, while expanding energy consumption may lead to the expansion of the economy. A number of studies have confirmed the growth hypothesis in developing countries. Akinlo (2009) investigated the causality relationship between energy consumption and economic growth for Nigeria and showed that there is a unidirectional Granger causality running from electricity consumption to real GDP. Similar findings in developing countries have been documented by Odhiambo (2009a) who used ARDL methods on Tanzania; Odhiambo (2010) who used ARDL methods in a trivariate framework for South Africa, Kenya and DRC and found the growth hypothesis to hold for South Africa and Kenya; and Abosedra et al. (2009) who used Granger causality tests on Lebanon. Narayan et al. (2008) estimated structural vector autoregressive (SVAR) models and provide similar evidence of the growth hypothesis following among developed (G7) countries.

3.4 The feedback hypothesis

The feedback hypothesis relates to the presence of bidirectional causality between electricity consumption and economic growth. This implies that causality flows between energy consumption and growth runs both ways and the processes are mutually reinforcing: electricity shocks hurt GDP growth and GDP shocks simultaneously hurt energy consumption. Odhiambo (2009b) uncovered a bidirectional Granger causality relationship between GDP and electricity consumption in South Africa using employment as an intermittent variable in a simple trivariate framework. Similar findings discussing a bidirectional relationship have been documented for Malawi (Jumbe 2004); India (Paul and Bhattacharya 2004); and Tunisia (Belloumi 2009); among other developing countries.

Summing up, the literature is not conclusive on the nature of the causal relationship between energy consumption and GDP growth. In the empirical analysis that follows, we will examine this relationship for Uganda. We will go further to examine the relationship between electricity consumption and the GDP components disaggregated following the major sectors of the economy in Agriculture, Industry and Services.

4 Methods

A major challenge in time series econometrics is that of non-stationarity that affects statistical inferences due to the possibility of spurious correlations. A convenient way of getting round this challenge is differencing the non-stationary data. However, this creates problems of loss of information of the data-generating processes in levels. However, if the variables under consideration are difference stationary, the vector error correction modelling (VECM) framework can be used in such a manner that avoids loss of information by modelling the linear combinations of the data in levels. We thus exploit the vector error correction modelling framework to investigate the relationship between GDP growth and electricity consumption in Uganda.

4.1 Vector error correction model

The k-dimensional VAR model with Gaussian errors $\varepsilon_t \sim iidN(0, \delta)$ can be expressed as:

$$X_t = A_1 X_{t-1} + \cdots + A_k X_{t-k} + \emptyset D_t + \varepsilon_t, \quad t = 1, \ldots, T. \tag{1}$$

The expression in Eq. (1) can be expressed in an error correction formulation. The error correction transformation combines both the levels and differences of the data as shown in Eq. (2), and the multicollinearity problem often present in time series data is reduced.

$$\Delta X_t = \alpha \beta' X_{t-1} + \sum_{i=1}^{k-1} r_i \Delta X_{t-i} + \varepsilon_t \tag{2}$$

where X_t is a vector of endogenous variables of interest, $\alpha\beta^{'}$ and r_i are the long-run and short-run coefficients to be estimated by the Johansen (1988) procedure. $i = 1, \ldots, k-1$ represents the optimal lags included in the system computed using appropriate lag selection criteria. If the variables in X_t are integrated of order one, I(1), then the long-run matrix $\alpha\beta^{'}$ can be said to be of reduced rank where α represents the adjustment parameters and β is the matrix of long-run coefficients.

In order to obtain the long-run equilibrium, we follow four steps outlined below: (1) we estimate the vector autoregressive model and obtain the optimal lag lengths in the first step; (2) following the Johansen procedure, we determine the number of cointegrating relationships in the long-run matrices $\alpha\beta^{'}X_{t-1}$ in the second step; (3) in the third step, we estimate the unrestricted cointegrating relations in the vector error correction model (based on Eq. 2) and tests of hypotheses (or imposition of implied restrictions) to determine the long-run equilibrium relationship. (4) Lastly, we test for model stability and residual analysis to check for normality, autocorrelation and heteroscedasticity of the models residuals in the fourth step.

4.2 Granger causality testing

The pair-wise Granger causality tests are carried out to identify the direction of causation between GDP growth and electricity consumption. A variable, say W_t, is said to Granger cause another variable, say X_t, if, given the past information or values of X_t, past values of W_t are useful in predicting X_t (Granger 1969).

Traditional pair-wise Granger causality testing, therefore, involves estimating the following systems of equations:

$$X_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} X_{t-i} + \sum_{i=1}^{k} \beta_{1i} W_{t-i} + \varepsilon_t \tag{3}$$

$$W_t = \beta_0 + \sum_{i=1}^{k} \alpha_{2i} W_{t-i} + \sum_{i=1}^{k} \beta_{2i} X_{t-i} + \mu_t \tag{4}$$

However, these conventional Granger causality tests have been criticised because they suffer some methodological shortcomings (see Odhiambo 2009a, b, 2010). Crucially, these tests do not consider the time series properties of the variables under consideration. Consequently, if the variables are cointegrated, these tests could suffer significant misspecification biases unless the lagged error correction terms are included (Granger 1988). Equally important, these tests do not allow us to test for both short-run and long-run Granger causality in a single framework.

Therefore, following Odhiambo (2009a), we test for both short-run and long-run Granger causality between electricity consumption and economic growth by estimating the following regressions:

$$\Delta \mathrm{LGDP}_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta \mathrm{LGDP}_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta \mathrm{LELEC}_{t-i} + \alpha_3 \mathrm{ECT}_{t-1} + \varepsilon_t \tag{5}$$

$$\Delta \text{LELEC}_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} \Delta \text{LELEC}_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta \text{LGDP}_{t-i} + \beta_3 \text{ECT}_{t-1} + \mu_t \tag{6}$$

All variables are defined as before: k represents the maximum lag length to be included in the models and ε_t and μ_t are error terms that are assumed to be identically and independently distributed. ECT_{t-1} is the error correction term obtained from the long-run cointegrating relationship. Short-run causality running from electricity consumption to GDP growth would be inferred by testing the joint significance of the coefficients α_{2i} using the F test. Likewise long-run causality would be inferred by testing the significance of α_3.

After determining the direction of causality between electricity consumption and GDP growth, we proceed further to examine dynamic causal relationships between sectoral output growth and electricity consumption. To the best of our knowledge, this is the first study focusing on developing countries and particularly in Sub-Saharan Africa to examine sectoral output effects of electricity consumption. A related study by Mirza et al. (2014) examined the effects of electricity conservation policies on sectoral output in Pakistan.

Testing for both short-run and long-run Granger causality between sector outputs and electricity consumption requires the estimation of the following systems of equations:

(a) Agricultural output and electricity consumption

$$\Delta \text{LAGRIC}_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta \text{LAGRIC}_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta \text{LELEC}_{t-i} + \alpha_3 \text{ECM}_{t-1} + \varepsilon_t \tag{7}$$

$$\Delta \text{LELEC}_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} \Delta \text{LELEC}_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta \text{LAGRIC}_{t-i} + \beta_3 \text{ECM}_{t-1} + \mu_t \tag{8}$$

(b) Industrial output and electricity consumption

$$\Delta \text{LIND}_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta \text{LIND}_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta \text{LELEC}_{t-i} + \alpha_3 \text{ECM}_{t-1} + \varepsilon_t \tag{9}$$

$$\Delta \text{LELEC}_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} \Delta \text{LELEC}_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta \text{LIND}_{t-i} + \beta_3 \text{ECM}_{t-1} + \mu_t \tag{10}$$

(c) Services output and electricity consumption

$$\Delta \text{LSERV}_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta \text{LSERV}_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta \text{LELEC}_{t-i} + \alpha_3 \text{ECM}_{t-1} + \varepsilon_t \tag{11}$$

$$\Delta \text{LELEC}_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} \Delta \text{LELEC}_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta \text{LSERV}_{t-i} + \beta_3 \text{ECM}_{t-1} + \mu_t \tag{12}$$

The error correction terms have been incorporated in all the models in Eqs. (5–12). However, in practice, only equations for which cointegration has been confirmed were estimated with an error correction term (see also Odhiambo 2009a, b).

5 Data

We use quarterly data spanning a 10-year period from Q1 2005 to Q1 2015. This dataset gives rise to 41 data points for each variable. The data that we use were collected from two sources. The GDP data including the sectoral value added in agriculture (AGRIC), industry (IND) and services (SERV) sectors were obtained from the new Uganda Bureau of Statistics (UBOS) rebased Quarterly GDP series. The electricity consumption data (ELEC) were obtained from the Electricity Regulatory Authority online databases. The data were transformed and presented in their natural logarithm forms. Transformed series are preceded with the letter "L". All GDP data are presented in constant or real terms. The descriptive characteristics of the individual data series are provided in Table 1.

5.1 Unit root testing

Testing of the data for unit roots followed the Dickey–Fuller Generalised Least Squares (DFGLS) procedure provided by Elliot et al. (1996). The DFGLS was preferred because of its superior performance and power, particularly in relatively small samples. As such the DFGLS was deemed better suited for our data as opposed to the ordinary (Dickey and Fuller 1979; Phillips and Perron 1988) tests. Unit root test results (Table 2) show that all variables have unit roots and therefore follow I(1) processes.

Table 1 Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
LGDP	41	9.231	0.196	8.856	9.523
LAGRIC	41	7.910	0.090	7.771	8.108
LIND	41	7.519	0.207	7.089	7.829
LSERV	41	8.509	0.218	8.086	8.828
LELEC	41	8.256	0.284	7.776	8.725

Table 2 Stationarity tests

Variable	DFGLS unit root test statics		Order of integration
	In levels	In first differences	
LGDP	0.649	−6.981***	I(1)
LELEC	0.185	−8.931***	I(1)
LAGRIC	0.143	−9.470***	I(1)
LIND	0.294	−7.936***	I(1)
LSERV	0.886	−7.045***	I(1)

*** Significance of the Elliott–Rothenberg–Stock DFGLS test statistic at the 1 % level

6 Results and discussion

6.1 GDP and electricity consumption

6.1.1 Lag length selection

The validity of empirical results depends on the careful specification and the appropriateness of the choice of the cointegrating rank specification of the underlying vector autoregressive (VAR) model. The formal testing of the lag structure carried out in this paper is based on the maximum likelihood function and is supported for our data by the Akaike Information Criteria (AIC), Schwartz Information Criteria (SIC), Hannan–Quinn Information Criteria (HQIC) and Final Prediction Error (FPE) lag reduction tests (Table 3).

The FPE, AIC and HQIC test procedures indicate an optimal lag structure of four (4), whereas the SBIC and LR indicate an optimal lag of one (1). We adopt a lag length of four (4) as indicated by the majority of selection criteria.

6.1.2 Testing for cointegration

After determining the lag structures of the data-generating processes, we use the Johansen (1988) procedure to test the existence of long-run equilibrium relations using the trace statistic test for cointegration. Because our data are based on rather small samples, the estimation procedure that we adopt accounts for the Bartlett correction following Johansen (2000). The Johansen cointegration procedure (Table 4) does not reject the null hypothesis of one cointegrating equation.

The Johansen trace and max test statistics suggest the existence of at least 1 cointegrating relationship between GDP and electricity consumption. Thus, we proceed to estimate this long-run relationship in a vector error correction framework.

The normalised cointegrating relationship between GDP and electricity consumption is shown in Table 5. Results indicate that electricity consumption is positively and significantly associated with GDP growth. Specifically, a 1 % increase in electricity consumption tends to increase GDP by 0.603 %. In addition, the error correct term shows that 59.2 % of disequilibria in this long-run relationship are corrected in each next time period (quarter).

Table 3 Lag length selection criteria

Lag	Log*L*	LR	FPE	AIC	SIC	HQIC
0	73.89027	NA	7.04e−05	−3.885961	−3.798884	−3.855262
1	147.9868	136.1773*	1.59e−06	−7.674960	−7.413730*	−7.582865
2	152.3265	7.506547	1.57e−06	−7.693324	−7.257941	−7.539831
3	157.7312	8.764347	1.46e−06	−7.769252	−7.159716	−7.554362
4	163.4480	8.652517	1.35e−06*	−7.862055*	−7.078365	−7.585767*

* Lag order selected by the criterion at 5 % level

Table 4 Cointegration test based on the trace and max tests

H_0	Trace test	Max test
$r = 0$	63.7112*	61.709*
$r = 1$	2.003	2.003

* Rejection of the hypothesis at the 5 % level

Table 5 Long-run equilibrium

Variable names	Coefficient	SE	*t* statistic
LGDP	1		
LELEC	−0.603	0.025	−23.867
Constant	−4.272		
Error correction	−0.592	0.229	−2.581

6.1.3 Granger causality and short-run dynamics

When variables are cointegrated, at least one or all of the error correction terms should be negative and statistically significant in the short-run model indicating showing convergence of the variables in the long run. As explained earlier, the joint significance of the differenced lagged coefficients of the independent variable indicates short-run Granger causality. Likewise the significance of the error correction term signifies long-run causality. Table 6 shows the short-run dynamics of the model.

The results indicate unidirectional long-run Granger causality running from electricity consumption to GDP growth. An important point to note here is that even though the error correction term in the electricity model is significant, it is positive which does not signify long-run convergence. Therefore we cannot conclude that GDP growth Granger causes electricity consumption. In addition, the *F* statistics for the joint significance of independent variables in both models do not provide sufficient evidence to support the existence of short-run Granger causality running in either direction (see Table 10).

6.2 Sectoral GDP and electricity consumption

6.2.1 Cointegration tests

In order to examine both the long-run and short-run the dynamic causality relationships between output in the different sectors and electricity consumption, we start by examining the cointegration in each sector following the Johansen (1988) multivariate approach. The Johansen approach is sensitive to the order specification and lag length criteria; for this matter, therefore, the series were ordered as X_{ti}, LELEC_t, where

Table 6 Granger causality and short-run dynamics

Variable	ΔLGDP	ΔLELEC
ECT_{t-1}	−0.592 (−2.59)**	0.547 (2.31)**
ΔLGDP_{t-1}	−0.013 (−0.05)	−0.404 (−1.61)
ΔLGDP_{t-2}	−0.091 (−0.39)	−0.237(−0.98)
ΔLGDP_{t-3}	0.037 (0.19)	−0.388 (−1.89)*
ΔLGDP_{t-4}	0.1445 (0.77)	0.109 (0.57)
ΔLELEC_{t-1}	−0.0149 (−0.23)	−0.075 (−1.11)
ΔLELEC_{t-2}	−0.040 (−0.62)	−0.042 (−0.64)
ΔLELEC_{t-3}	−0.065 (−0.64)	−0.066 (−1.04)
ΔLELEC_{t-4}	−0.066 (−1.21)	−0.141 (−2.50)**
Constant	0.031 (3.04)***	0.034 (3.19)***

The coefficients are tabulated; *t* values are in parentheses

*** Significance at the 1 % level

** Significance at the 5 % level

* Significance at the 10 % level

$i = (1, 2, 3)$ represents the Agriculture, Industry, and Services sectors, respectively. The cointegration tests were estimated with a lag length of 1 in the agriculture and industrial sectors and a lag of length of 3 in the services sector.

The cointegration tests (Table 7) confirm the existence of long-run cointegrating relationships between electricity consumption and sectoral output in the industrial and services, but not in the agricultural sectors. The absence of a valid long-run relationship in the agricultural sector implies that we cannot infer long-run causality.

Results in Table 8 indicate that electricity consumption is positively and significantly associated with industrial and services sector output growth. Specifically, a 1 % increase in electricity consumption is associated with a 0.593 % increase in industrial output and a 0.692 % increase in services output. In addition, the error correction term for the industrial sector shows that 21.5 % of disequilibria in this long-run relationship are corrected in each proceeding time period (quarter). However, the error correction term for the services sector is not significant at any of the conventional levels. This might imply that the long-run relationship is weak.

6.2.2 Sectoral Granger causality tests and short-run dynamics

The sectoral short-run dynamics are presented in Table 9. We did not infer cointegration in the agricultural sector, and therefore the error correction terms for the long-run relationship are not available. None of the explanatory variables in the agricultural sector models are significant. This implies no short-run Granger causality in either direction in the agricultural sector. This result confirms the neutrality hypothesis in the causal relationship between electricity consumption and growth in the agricultural sector.

The error correction term in the industrial sector is negative and statistically different from zero, implying that there is long-run causality running from electricity

Table 7 Sectoral cointegration tests

H_0	Agricultural sector		Industrial sector		services sector	
	Trace test	Max test	Trace test	Max test	Trace test	Max test
$r = 0$	13.201	13.094	17.101*	16.476*	15.494*	14.264*
$r = 1$	0.107	0.107	0.625	0.625	0.409	0.409

* Rejection of the hypothesis at the 5 % level

Table 8 Sectoral long-run equilibrium relationships

	Industrial sector	Services sector
LIND	1	–
LSERV	–	1
LELEC	−0.593 (−9.76)***	−0.692 (−35.96)***
Constant	−2.611	−2.774
ECT (−1)	−0.215 (−2.42)**	−0.104 (−1.24)

The coefficients are tabulated; *t* values are in parentheses

*** Significance at the 1 % level

** Significance at the 5 % level

* Significance at the 10 % level

Table 9 Sectoral short-run dynamics

Variable	Agricultural sector		Industrial sector		Services sector	
	ΔLAGRIC	ΔLELEC	ΔLIND	ΔLELEC	ΔLSERV	ΔLELEC
Long run						
ECT_{t-1}	–	–	−0.215 (−2.42)**	0.4034 (2.28)**	−0.104 (−1.24)	1.239 (10.25)***
Short run						
$\Delta LELEC_{t-1}$	0.093 (1.26)	−0.438 (−2.89)***	0.004 (0.05)	−0.354 (−2.48)**	−0.065 (−1.08)	−0.025 (−0.29)
$\Delta LELEC_{t-2}$					0.022 (0.38)	0.035 (0.42)
$\Delta LELEC_{t-3}$					−0.023 (−0.44)	0.028 (0.38)
$\Delta LAGRIC_{t-1}$	0.588 (−4.49)***	0.0694 (0.26)				
$\Delta LIND_{t-1}$			−0.279 (−1.89)*	0.314 (1.07)		
$\Delta LSERV_{t-1}$					−0.029 (−0.16)	−0.921 (−3.45)***
$\Delta LSERV_{t-2}$					−0.461 (−3.03)***	−0.740 (−3.39)***
$\Delta LSERV_{t-3}$					−0.067 (−0.39)	−0.497 (−1.98)*
Constant	0.009 (1.30)	0.027 (1.98)*	0.027 (3.93)***	0.014 (1.05)	0.032 (3.83)***	0.003 (0.23)

The coefficients are tabulated; *t* values are in parentheses

*** Significance at the 1 % level

** Significance at the 5 % level

* Significance at the 10 % level

consumption to industrial output. However, this causality is not existent in the short run as the explanatory variables are jointly insignificant. Moreover, there is no reverse causality running from industrial output to electricity growth as the error correction term is positive, signifying a lack of long-run convergence.

In the services sector, the error correction term is negative as expected but statistically insignificant, implying absence of long-run causality. In addition, the *F* test for the joint significance of the independent variables indicates no short-run causality running from electricity consumption. We do not find reverse long-run causality running from services sector growth to electricity consumption. However, the *F* test indicates short-run causality running from services sector to electricity consumption. The services sector in Uganda is large, contributing about 54 % of GDP. However, the low energy intensity in the Ugandan services sector explains the absence of long- and short-run causality running from electricity consumption to services sector growth. Table 10 provides the summary results of the t and F statistics both for the long-run and short-run causality relationships.

7 Conclusions and policy implications

This paper examined the causal relationship between electricity consumption and sectoral output growth in Uganda. Although a number of studies have examined the relationship between electricity consumption and economic growth, only very few—if

Table 10 Summary of causality tests

No.	Null hypothesis	*t* test on ECT	*F* test	Conclusion	
				Short run	Long run
1.	Electricity consumption does not Granger cause GDP	6.66 (0.016)**	0.42 (0.794)	ELE ≠ GDP	ELEC → GDP
2.	GDP does not Granger cause electricity consumption		1.92 (0.137)	GDP ≠ ELEC	GDP ≠ ELEC
3.	Electricity consumption does not Granger cause agriculture		1.59 (0.214)	ELEC ≠ AGRIC	ELEC ≠ AGRIC
4.	Agriculture does not Granger cause electricity consumption		0.07 (0.798)	AGRIC ≠ ELEC	AGRIC ≠ ELEC
5.	Electricity consumption does not Granger cause industry	5.84 (0.021)**	0.00 (0.957)	ELEC ≠ IND	ELEC → IND
6.	Industry does not Granger cause electricity consumption		1.15 (0.291)	IND ≠ ELEC	IND ≠ ELEC
7.	Electricity consumption does not Granger cause services	1.54 (0.224)	0.99 (0.411)	ELEC ≠ SERV	ELEC ≠ SERV
8.	Services does not Granger cause electricity consumption		7.48 (0.001)***	SERV → ELEC	SERV ≠ ELEC

The test statistics are tabulated; *p* values are in parentheses

Causality relationships: → and ≠ denote unidirectional causality and no causality, respectively

*** Significance at the 1 % level

** Significance at the 5 % level

* Significance at the 10 % level

any—have examine the dynamic sectoral linkages. This study therefore provides novel insights in the sectoral output growth and electricity consumption dynamics in Uganda.

We proceeded in three ways. First, we used vector error correction techniques to estimate the long-run relationship between electricity consumption and GDP growth. Second we applied Granger causality tests to determine the direction of this relationship. Third, we disaggregated GDP into its major sectors of agriculture, industry and services, and tested for Granger causality between sectoral output and electricity consumption.

Results suggest a long-run unidirectional long-run causal relationship running from electricity consumption to GDP. This result confirms the growth hypothesis for Uganda and is similar to earlier findings by among others; Akinlo (2009), Odhiambo (2009a, 2010), Abosedra et al. (2009), and Narayan et al. (2008).

At the sectoral level, only the industrial output has demonstrated long-run causality running from electricity consumption to output. In the services sector, results have shown a unidirectional short-run causality relationship running from services sector output to electricity consumption. In the agricultural sector, the neutrality hypothesis was confirmed whereby no causal relationship was established. We can therefore conclude that the observed causal relationship between electricity consumption and GDP is supported by the dynamic growth effects in the industrial sector. This is perhaps not surprising given that, as discussed earlier, industrial production accounts for 63 % of electricity consumption in Uganda.

These results suggest that current efforts to improve electricity generation will accelerate growth in Uganda by facilitating industrial sector growth. Moreover, results suggest electricity conservation policies can be applied in the services sector without hurting growth.

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Competing interests
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