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Electricity Consumption and Economic Growth: Trivariate investigation in Botswana with Capital Formation

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ABSTRACT: This study investigates the relationship between electricity consumption and real gross domestic product in Botswana (the world's largest producer of diamonds). The study includes capital formation in a trivariate system for the period covering 1980-2008. Zivot and Andrews (1992) unit roots test; bound test for cointegration, and Granger causality test are employed. Unidirectional causality is found from electricity consumption to real gross domestic product is in line with study of Altinay and Karagol (2005) among others. The long run estimate reinforce the Granger causality tests by indicating that electricity consumption is positively associated with real gross domestic product in the long run. Further findings suggest unidirectional causality from capital formation to real gross domestic product. The implication is that Botswana- being a highly energy dependent country- will have the performance of its capital formation on the economy partly determined by adequate electricity.

Keywords: Economic growth, Electricity consumption, Bound test, Causality, Structural break, Botswana
JEL Classification: Q43; C32; O55

1. Introduction

Electricity plays an essential role in modern life, bringing benefits and progress in various sectors, including transportation, manufacturing, mining and communication sectors. Electric power is vital for economic growth and quality of life not only because it fosters the productivity of capital, labour and other factors of production, but also that increased consumption of energy, particularly commercial energy like electricity signifies high economic status of a country (Jumbe, 2004). These facts have attracted authors to investigate the role of electricity in different countries. Starting with the pioneering work of Kraft and Kraft (1978), most authors have utilised causality tests to investigate the relationship between electricity consumption and economic development. Further advances in time series techniques and availability of long time series data on electricity have stimulated further research in this area (see Tang, 2008; Altinay and Karagol, 2005; Shiu and Lam, 2004; Narayan and Singh, 2007).

In recent times, some authors have decided to focus on African countries (see Akinlo, 2009; Kouakou, 2011; Odhiambo, 2009a, b; Jumbe, 2004; Wolde-Rufael, 2006; Squalli, 2007). Conspicuously from all these studies is that Botswana-the largest producer of diamond in the world-was not included. This is despite the fact that Botswana remains one of the countries in Africa with consistent electricity deficit, which reached its peaked in 2008 at 1174.83 Kilo-watts (KWh) per capita (which is due to declining electricity generation and persistent increase in electricity consumption). Botswana is a country, which depends on imported electricity to the tune of 80% (EIA, 2011; Jefferis, 2008). Besides, the electricity usage among household insufficiently increased from 10% in 1991 to 25% in 2001. Rural access to electricity was merely 40.75% in 2008. Given the unfavourable conditions, the Government's "Vision-2016 plan" aims at 100% electrification to support the broader development goals of access to education and health, as well as employment opportunities, to the rural

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and the disadvantaged population (AFDB, 2009). Capital investment is seen as bedrock to achieve this vision. Thus, Botswana Power Corporation (BPC) proceeded in 2007 and 2008, to invest 343.4 million pula and 17.3 million pula, respectively in electricity infrastructure (Lekaukau, 2007; Rakhudu, 2008).

Besides, the study notes that with the exception of Odhiambo (2009b) and Ouédraogo (2009) most of these studies on African countries employ bivariate analysis. However, Akinlo (2009) argues that this may create omitted variable bias. In addition, studies on African countries have ignored structural breaks in testing for the unit root tests. The seminal work of Perron (1989) has shown that structural change can substantially reduce the power of unit root tests. In other words, failure to allow for an existing break leads to bias that reduces the ability to reject a false unit root null hypothesis. Therefore, bias resulting from unit root test will affect the inferences made from the subsequent cointegration test and ultimately the causality tests.

Against these backdrops, the study intends to investigate the relationship between electricity consumption and real gross domestic product in Botswana for the period 1980-2008. The study will provide for capital investment in a trivariate system. Furthermore, the study intends to utilise Zivot and Andrews (1992) method to endogenously determine structural breaks while conducting the unit root tests. The rest of the paper is organized as follows. Section 2 provides an overview of electric power in Botswana and Section 3 cover a brief review of literature related to energy consumption and economic growth. Section 4 outlines the methodology used in the study. Following, Section 5 provides the empirical findings of the research and the last section concludes the study.

2. Overview of electric power in Botswana

Botswana is a landlocked country located in Southern Africa sharing border with Namibia (1,360 km), South Africa (1,840 km) and Zimbabwe (813 km). The size of Botswana is 581,730 sq km with landmass accounting for 566,730 sq km and water accounting for 15,000 sq km (CIA, 2011). From a humble beginning as an agrarian economy at independence in 1966, the discovery of diamonds in 1967 transformed the country's economy, culminating into becoming the world's leading diamond producer (MFDP, 2003). For the review period 2001-2005, diamonds accounted for the largest portion of the country's total foreign exchange revenues. The economic growth per capita was high at 7.540% in 2002 and despite the global downturn; the Botswana was still able to grow at 3.278% and 1.579% in 2007 and 2008, respectively. In 2007, the growth of manufacturing value added was 17.476%. The youth literacy was high at 95.100% in 2008 (WDI, 2010). Key to Botswana maintaining its successful development path is the energy sector. Botswana's energy demand was about 3660 Gigawatt hour (GWh) in 2008 (peak load of 500 megawatt), which is projected to grow at about 6% per annum reaching 5300 GWh by 2017 (peak load of 850 megawatt) and 6890 GWh by 2026 (peak load of 1130 megawatt). However, the deepening energy crisis across the Southern Africa sub-region is a major impediment to Botswana's economic growth plans, poses a threat to stability, and requires a major concerted effort at the national and regional levels to address the energy challenge (AFDB, 2009).

Generally, in the Southern African region, the main source of electricity is coal-fired power. In Botswana, the case is not different. As shown in Table 1, the percentage of coal-fired power has been increasing over the years. For instance, the contribution of coal-fired power was 78.172% in 1990 and rose to 95.277% and 99.464% in 1985 and 2007, respectively (WDI, 2010). The other source of electricity has been majorly through small-scale oil–sourced power. The preference for coal-fired power over the oil-sourced power has been majorly due to costs differences as the latter is far more expensive. It is estimated that coal-fired power costs 6-8 US cent per KWh, while oil-sourced power costs around 25-35 cent per KWh (Jefferis, 2008). This indicates that Botswana electricity tariffs are still relatively low by world – and African – standards. Besides, Botswana, like several other countries in the Southern Africa sub region relies on inexpensive, abundant, and reliable electricity from South Africa. In recent years, around 80% of electricity is imported, of which 70% is from the national electric utility of South Africa-Eskom. The domestic supply of around 20% comes from Botswana Power Corporation (BPC), which is the sole electricity company over the entire country and has a mandate of supplying the country with power. In 2008 alone, Botswana imported about 2440 GWh (67% of its power requirements) from Eskom, while its own small 25-year-old coal power plant (Morupule A, 4 x 33 MW) provided about 22% (AFDB, 2009). In addition, the BPC controls the network of transmission and distribution lines to transport electricity from the power station, or point of import to eventual consumers. Based on the recommendation of a steering committee by the government on the need to privatise, decentralised BPC, the Electricity Supply Act of 1973 was amended in 2007 to permit independent electricity suppliers (Marandu, 2010).

Table 1. Botswana electricity sources

Year	Coal	Oil
1981	78.172	21.828
1985	95.277	4.723
1990	88.079	11.921
1995	97.983	2.017
2000	97.149	2.851
2005	99.382	0.618
2006	99.424	0.576
2007	99.464	0.536

Source: World Development Indicators (2010)

With these sources, generation of electricity has been falling over the years. For instance, Fig. 1 shows that net electricity generation fell from 760.004 KWh per capita (GENERATION) in 1992 to 542.6519 KWh per capita in 2001 and further fell to 308.674 KWh per capita in 2008. One reason for this is that BPC supply has been declining slowly, presumably reflecting the aging of the power station and the resulting maintenance needs (Jefferis, 2008). On the other hand, electricity consumption has been rising over time. The electricity consumption was 762.687 KWh per capita (ELECTRICITY) in 1992; 1156.209 KWh per capita in 2001; and in the year 2008, the figure rose to 1483.508 KWh per capita. This has resulted into electricity deficit exacerbating over the years, as it was 2.682 KWh per capita in 1992, 613.557 KWh per capita in 2001, and 1174.83 KWh per capita in 2008. In order to solve this problem, the rural electrification programme was accelerated with the connection of 72 villages over the period September 1999 to December 2001. For the financial year 2006/07, the government set aside funds to electrify villages (Marandu, 2010). More recently, the rural electrification plan is being addressed by implementing two main projects namely, the 100 Villages and the 30 Villages Electrification Projects. The 100 Villages Electrification Project is funded by the Government of Botswana through a loan from Swedish and Norwegian banks amounting to US Dollar 89 million (Motsepe, 2009). Hence, between 2004 and 2007, rural access to electricity doubled to 44%, though short of the 60% target under the National Development Plan (AFDB, 2009).

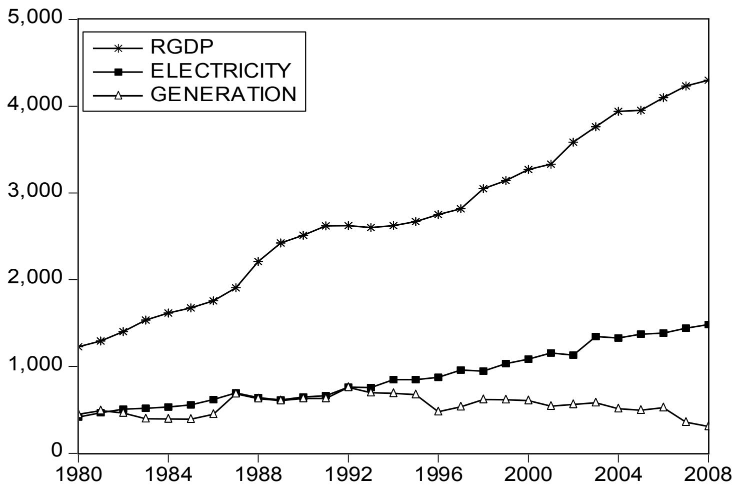

Fig. 1 Trend in electricity consumption, electricity generation and RGDP, 1980–2008

The efforts will be futile if the target- ELECTRICITY does not have any correlation or positive impact on the economy. However, Fig. 1 indicates that ELECTRICITY has been very close to the real economic activities-real gross domestic product per capita (RGDP). It is shown that in the years 1992, 2001 and 2008; RGDP rose from US 2622.549 dollars, to US 3333.276 dollars, and further to US 4299.7492 dollars, respectively (WDI, 2010; EIA 2011). This association does indicate whether economic growth is dependent on energy consumption or vice versa. Causality running from RGDP to ELECTRICITY implies that Botswana is not entirely dependent on energy for its economic growth, while causality running from electricity consumption to economic growth, for example, implies that economic growth is dependent on energy consumption. Therefore, econometrics methods are required to examine the relationship between ELECTRICITY and RGPD in Botswana. Before investigating the nexus econometrically, we review some existing literatures on the subject matter.

3. Review of related studies

The investigation of the relationship between energy consumption and economic growth started with the seminal work of Kraft and Kraft (1978) on USA (See Ozturk, 2010 for a detailed survey of literature on energy-growth nexus). Subsequently, numerous authors specifically concentrated on the relationship between electricity consumption and economic development (see Ghosh, 2002; Jamil and Ahmad, 2010; Ho and Siu, 2007; Shiu and Lam, 2004; Narayan and Singh, 2007). Although with conflicting results, most of these works have several similarities. An obvious similarity is the utilisation of causality tests to investigate the relationship. This is even applicable to multi-country studies (see; Narayan and Prasad, 2008; Acaravci and Ozturk, 2010; Ozturk and Acarvci, 2011; Narayan and Smyth, 2009; Yoo, 2006; Chen, Kuo and Chen, 2007). The other similarity is that unidirectional causality running from gross domestic product to energy consumption is interpreted to mean that a country is not exclusively dependent on energy for its economic growth, and that power conservation policies can be undertaken with insignificant or no adverse effects on economic growth (Odhiambo, 2010). On the other hand, unidirectional causality running from real gross domestic product electricity consumption is interpreted to mean that a country is not entirely dependent on energy for its economic growth, and that energy conservation policies can be implemented with modest or no undesirable effects on economic growth (Narayan and Singh, 2007; Odhiambo, 2009a).

The studies on Africa are also characterised by conflicting results and utilisation of causality tests. For example, on Nigeria, Akinlo (2009) investigates the causality relationship between energy consumption and economic growth for period 1980-2006, using Granger causality test, Johansen and Juselius (1990) cointegration test. The results show that real gross domestic product and electricity consumption are cointegrated and there is unidirectional Granger causality running from electricity consumption to real gross domestic product. Using the data from 1971 to 2008, Kouakou (2011) investigates the causal relationship between the electric power industry and the economic growth of Cote d'Ivoire. The findings reveal bidirectional causality between per capita electricity consumption and per capita gross domestic product in the short run, but a unidirectional causality from electricity to gross domestic product in the long run.

In another study with similar findings, Odhiambo (2009a) examines the relationship between energy consumption with economic growth in Tanzania for the period 1971-2006. The study utilises the Granger causality tests, but unlike Akinlo (2009), the study employs bounds testing approach for cointegration. Furthermore, energy is proxy by total energy consumption per capita and electricity consumption per capita. Generally, Odhiambo (2009a) observe that there is a stable long run relationship between each of the proxies of energy consumption and economic growth. More importantly, the results of the causality test, on the other hand, show that there is unidirectional causal flow from total energy consumption to economic growth.

Jumbe (2004) examines relationship between electricity consumption and respectively, overall gross domestic product, agricultural gross domestic product and non-agricultural gross domestic product using Malawi data for period 1970-1999. With residual-based cointegration, the results suggest that electricity consumption is respectively, cointegrated with gross domestic product and non-agricultural gross domestic product, but not with agricultural gross domestic product. The Granger causality tests suggest bidirectional causality between electricity consumption and gross domestic product, but a unidirectional causality running from non-agricultural gross domestic product to electricity consumption. Further, Jumbe (2004) examines the elasticity of the variables, with the findings indicating that the impact of electricity consumption is only significant in the long run.

There are also multi-country studies on Africa. These include Wolde-Rufael (2006) who considers 17 African countries for the period 1971-2001 in investigating the long run and causal relationship between electricity consumption per capita and real gross domestic product per capita. The paper adopts the bound test for cointegration; in addition to the causality test propose by Toda and Yamamoto (1995). The findings reveal unidirectional causality flowing from electricity consumption per capita to real gross domestic product per capita for Benin Congo, DR and Tunisia. On the other hand, the results suggest unidirectional causality flowing from real gross domestic product per capita to electricity consumption per capita Cameroon, Ghana, Nigeria, Senegal Zambia and Zimbabwe. Wolde-Rufael (2006) reports bidirectional causality on Egypt, Gabon and Morocco, while no causality on Algeria, Congo Rep. Kenya, Sudan and South Africa. Another multi-country work that includes African countries is Squalli (2007). In contrary to Wolde-Rufael (2006), Squalli (2007) notes unidirectional causality from economic growth to electricity consumption for Algeria; and a bidirectional relationship between economic growth to electricity consumption for Nigeria.

Beyond the similarity of using causality tests, it is obvious to note that the studies are based on bivariate analysis. This creates the danger of omitted variable bias that could result from the use of bivariate analysis (Akinlo 2009). Hence, Odhiambo (2009b) provide for omitted variable by including employment in a study of South for the period 1971 to 2006. The findings suggest that there is bidirectional causality between electricity consumption and economic growth in South Africa. Moreover, the study shows that employment in South Africa Granger causes economic growth.

The other study with a trivariate system is Ouédraogo (2009) who investigates the nexus on Burkina Faso by adding capital formation to the system, for the period 1968-2003. Using Granger causality, the findings reveal that there is a bidirectional relationship between electricity consumption and real gross domestic product in the short-run and the long run. Besides, there is also evidence of a positive feedback relationship between gross domestic product and capital formation. However, the study shows no causal relationship between electricity consumption and capital formation.

From the foregoing reviewed literatures on Africa, it is pertinent to note that there is no previous study on Botswana despite the electricity situation cum the efforts and targets of the authorities in the country. Moreover, literatures on Africa does not provide for structural breaks. Only a handful of literatures (Odhiambo, 2009b; Ouédraogo, 2009) utilise a trivariate system. Thus, the methodology discussed in the next section provide for all these deficiencies.

4. Methodology and data

4.1 Model

In investigating the relationship between electricity consumption and output growth, the study follows a neo-classical one-sector aggregate production model proposed by Ghali and El-Sakka (2004) that treats capital, labour, and energy(in our case, electricity) as separate inputs. This implies that:

$$RGDP_t = (CAPITAL_t \;\; LABOUR_t \;\; ELECTIRICITY_t) \tag{1}$$

Where *RGDP* is the aggregate output of real GDP; *CAPITAL* is the capital stock; *LABOUR* is the level of employment; *ELECTRICITY is* total electricity consumption, and the subscript t denotes the time period. The study computes per capita form of the variables by dividing through by *LABOUR* and then taking the logarithmic form of (1). This results in:

$$RG\dot{D}P_t = \alpha(CAP\dot{I}TAL)_t + \beta(ELECT\dot{R}ICITY)_t \tag{2}$$

where the dot above each variable indicates that each variable is in per capita form. The constant parameters α and β measures the marginal effect of capital and electricity, respectively on output. The production function (1) suggests that long-run movements of the variables may be related (Ghali and El-Sakka, 2004). Furthermore, for short-run dynamics in factor-input behaviour, the specification in (2) would suggest that past changes in variables such as capital and electricity could contain useful information for predicting the future changes of output, ceteris paribus (Lorde, Waithe and Francis, 2010). In other words, causality tests can be utilised to examine the relationship among the variables.

4.2 Data

This study uses annual data for the period 1980-2008. The study sources its real gross domestic product and gross capital formation data from the World Bank's World Development Indicators (WDI) 2010. The annual data of real gross domestic product per capita (RGDP) and gross capital formation (which was subsequently divided by population figure from WDI to arrive at the per capita figures) are in US dollars (2000=100). Studies such as Wolde-Rufael (2009) Ouédraogo (2009), Apergis and Payne (2009), Narayan and Smyth (2008) utilised capital formation (CAPITAL) to proxy the stock of physical capital. The electricity consumption figure is obtained from the Energy Information Administration (EIA) website and subsequently divided by population figure from WDI to arrive at the electricity consumption per capita in KWh (ELECTRICITY). All the variables are expressed in natural logarithmic form.

4.3 Stationarity test

Traditionally, unit root tests are investigated using Augmented Dickey-Fuller test or ADF as developed by Said and Dickey (1984) and Phillip and Perron (1988) test or PP, which control for serial correlation. However, Perron (1989) shows structural change can substantially reduce the power of unit-root tests and proposes a unit root model, with an exogenous structural break. Exogenous structural break has been, in turn criticised on the basis that it leaves room for arbitrarily selection of dates. Hence, Zivot and Andrews (1992) propose a variation of Perron (1989) original test by assuming that the exact time of the break point is unknown. Instead, a data dependent algorithm is used to proxy Perron (1989) subjective procedure to determine the break points. Zivot and Andrews (1992) developed three models to test for unit root. In this study, we employ the first two of the three Zivot and Andrews (1992) methods, which are specified below:

$$Model \quad A: \ \Delta Y_t = \mu_1{}^A + \gamma_1{}^A t + \mu_2{}^A DU_t(\lambda) + \alpha^A Y_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta Y_{t-j} + \varepsilon_t \tag{3}$$

$$Model \quad B: \ \Delta Y_t = \mu_1{}^B + \gamma_1{}^B t + \gamma_2{}^A DT^*{}_t(\lambda) + \alpha^B Y_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta Y_{t-j} + \varepsilon_t \tag{4}$$

where $DU_t(\lambda)$ is 1 and $DT_t^*(\lambda) = t - T\lambda$ if $t > T\lambda$, 0 otherwise. $\lambda = {}^{T_B}\!/\!_{T}$ and T_B represents a possible break point. The null hypothesis is $\alpha = 0$ while the alternative hypothesis is $\alpha < 0$ implying that the series is a trend-stationary process with a one-time break occurring at an unknown point in time. Zivot and Andrews (1992) considers all points as a potential break-date (T_B) and runs a regression for every possible break-date sequentially. Hence, the break-date (T_B) eventually selected represents the date, which minimizes the one-sided t-statistic from amongst all possible break points (T_B). Generally, Model A allows for a change in the level of the series, while Model B allows for a change in the slope of trend of a series.

4.4 Cointegration

Sequel to the stationarity test is the cointegration test in which the study utilises bound tests of the autoregressive distributed lag (ARDL) approach as articulated by Pesaran and Shin (1999) and extended by Pesaran, Shin and Smith (2001). There are several reasons for the adoption of this technique. As against the conventional Johanssen cointegration method that uses system of equation to estimate long run relationship, ARDL employs a single reduced form equation. Moreover, the approach does not require pre-testing variables, hence it could be implemented regardless of whether the underlying variables are I(0), I(1), or fractionally integrated, thereby reducing the task of establishing the order of integration amongst the variables. Moreover, the long and short-run parameters of the model are estimated simultaneously. As a result, the inability to test hypotheses on the estimated coefficients in the long run associated with the Engle-Granger method is avoided. Procedurally, ARDL involves investigating the existence of a long run relationship using the following unrestricted error correction models (UECMs):

$$\Delta \ln RGDP_t = \alpha_{10} + \sum_{i=1}^{p} \alpha_{11} \Delta \ln RGDP_{t-1} + \sum_{i=0}^{p} \alpha_{12} \Delta \ln CAPITAL_{t-1} + \sum_{i=0}^{p} \alpha_{13} \Delta \ln ELECTRICITY_{t-1} + \delta_{11} \ln RGDP_{t-i} + \delta_{12} \ln CAPITAL_{t-1} + \delta_{13} \ln ELECTRICITY_{t-i} + \varepsilon_{1t} \quad (5)$$

$$\Delta \ln CAPITAL_t = \alpha_{20} + \sum_{i=1}^{p} \alpha_{21} \Delta \ln CAPITAL_{t-1} + \sum_{i=0}^{p} \alpha_{22} \Delta \ln RGDP_{t-1} + \sum_{i=0}^{p} \alpha_{23} \Delta \ln ELECTRICITY_{t-1} + \delta_{21} \ln CAPITAL_{t-i} + \delta_{22} \ln RGDP_{t-1} + \delta_{23} \ln ELECTRICITY_{t-i} + \varepsilon_{2t} \quad (6)$$

$$\Delta \ln ELECTRICITY_t = \alpha_{30} + \sum_{i=1}^{p} \alpha_{31} \Delta \ln ELECTRICITY_{t-1} + \sum_{i=0}^{p} \alpha_{32} \Delta \ln RGDP_{t-1} + \sum_{i=0}^{p} \alpha_{33} \Delta \ln CAPITAL_{t-1} + \delta_{31} \ln ELECTRICITY_{t-i} + \delta_{32} \ln RGDP_{t-1} + \delta_{33} \ln CAPITAL_{t-i} + \varepsilon_{3t} \quad (7)$$

In the three specifications above Δ represents first difference operator, *ELECTRICITY* is the per capita electricity consumption, *RGDP* is the per capita gross domestic per capital and *CAPITAL* is capital formation per capita. Hence, a joint significance test, which implies no cointegration (H_0: $\delta_{11} = \delta_{12} = \delta_{13} = 0$: $\delta_{21} = \delta_{22} = \delta_{23} = 0$: $\delta_{31} = \delta_{32} = \delta_{33} = 0$) is conducted on (5), (6) and (7). The F-test is considered in determining whether a long-run relationship exists among the variables through testing the significance of the lagged levels of the variables. If the computed F-statistic exceeds the upper critical value, then there is cointegration. If the F-statistic falls within the two bounds of critical values then the test becomes inconclusive. Finally, if the F-statistic is below the lower critical value, it implies no cointegration.

4.5 Causality test

Granger (1988) integrated the concept of cointegration into causality. With cointegrated variables, Granger (1988) stated that causal relations among variables can be examined within the framework of the ECM. While the short run dynamics are captured by the individual coefficients of the lagged terms, the error correction term contains the information of long run causality. Hence, significance of each explanatory variable lags depict short run causality. On the other hand, a negative and statistical significant error correction term is assumed to signify long run causality. The equations are stated below:

$$\Delta \ln RGDP_t = \alpha_{40} + \sum_{i=1}^{q} \alpha_{41} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{q} \alpha_{42} \Delta \ln CAPITAL_{t-1} + \sum_{i=1}^{q} \alpha_{43} \Delta \ln ELECTRICITY_{t-1} + \varphi_1 ECT_{t-1} + \varepsilon_{4t} \quad (8)$$

$$\Delta \ln CAPITAL_t = \alpha_{50} + \sum_{i=1}^{q} \alpha_{51} \Delta \ln CAPITAL_{t-1} + \sum_{i=1}^{q} \alpha_{52} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{q} \alpha_{53} \Delta \ln ELECTRICITY_{t-1} + \varphi_2 ECT_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta \ln \mathrm{ELECTRICITY}_t = \alpha_{60} + \sum_{i=1}^{q} \alpha_{61} \Delta \ln ELECTRICITY_{t-1} + \sum_{i=1}^{q} \alpha_{62} \Delta \ln RGDP_{t-1} + \sum_{i=1}^{q} \alpha_{63} \Delta \ln CAPITAL_{t-1} + \varphi_3 ECT_{t-1} + \varepsilon_{6t} \quad (10)$$

where *ECT* stands for the error correction term, which is derived from the long run cointegration relationship and must be significant for long run causality to exist. Moreover, φ must produce a negative sign for causality to exist in the long run.

4.6 Diagnostic test

The study conducts diagnostics tests such as Breusch-Godfrey test to check the null hypothesis of no autocorrelation, as against the use of Durbin Watson test, which loses its power in the presence of a lagged dependent variable. Besides, the study adopts the Jarque and Bera (1980) tests popularly called the Jarque and Bera tests for the normality test, which encompasses other forms of detecting normality- Skweness and Kurtosis. In fact, it is a weighted average of the squared sample moments corresponding to Skweness and excess kurtosis. Under the null hypothesis, it is distributed as Chi-Squared with two degree of freedom (Verbeek, 2004). In testing for the functional form of the equation, the study employs the Ramsey (1969) RESET test (regression equation specification error tests), which tests whether additional terms of the regressors variables are significant in the auxiliary regression. The significance of these additional variables indicates that the model is misspecified (see Gujarati, 2003). The diagnostics tests include Autoregressive Conditional Heteroscedasticity (ARCH) test for heteroscedasticity.

In testing for the stability of parameters and regressions, the study utilises the Brown, Durbin and Evans (1975) tests popularly known as cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests, which are based on the recursive regression residuals. The CUSUM and CUSUMSQ statistics are updated recursively and plotted against the model's break points. Thus, the coefficients of a given regressions are stable if the plots of the statistics fall within critical bounds of 5% significance. Generally, CUSUM and CUSUMSQ tests are conducted through graphical representation.

The study selects CUSUM and CUSUMSQ tests ahead of other forms of stability tests because CUSUM and CUSUMSQ tests overcome shortcomings of the other stability tests. For example, Chow (1960) introduce Chow test that requires a priori knowledge of structural breaks in the estimation period, which may not be known hence need to be determined arbitrarily. The Chow test ignores the difference on the account of intercepts, slopes or both (Gujarati, 2003) and it is only valid under homoscedasticity (Wooldridge, 2009). Armed with all the foregoing methods, the study provides the empirical findings in the following section.

5. Results and findings

The results for the ADF and PP unit root tests for RGDP, CAPITAL and ELECTRICITY are reported in Table 2. The ADF and PP tests produce identical outcomes. The null hypothesis that the variables are nonstationarity cannot be rejected for any of the series at level, but when the data are first differenced, the null that the series contain unit root can be rejected for all variables with RGDP at 10%. This implies that RGDP, CAPITAL and ELECTRICITY are I(1). However, the results may not be valid because of structural breaks. Therefore the study proceeds with a method that incorporates structural break.

Table 2. ADF and PP tests for unit roots

Variables	Levels		First differences	
	ADF	PP	ADF	PP
RGDP	-1.980	-2.321	-2.742*	-2.754*
CAPITAL	-0.907	-0.471	-4.068***	-4.043***
ELECTRICITY	-0.971	-1.700	-4.201***	-8.381***

The lag selection of the ADF is based on AIC with a lag length of 1. The PP test is estimated based on Bartlett kernel with Newey-West bandwidth. Generally, the specification of the tests include intercept only; critical values are based on Mackinnon (1996) and the null hypothesis is that of no stationarity.
*, *** Imply stationarity at 10% and 1% level of significance, respectively.

The results of the Zivot and Andrews (1992) model A and model B unit root tests in the presence of one unit root are reported in Table 3. Coincidentally, the findings are similar to the unit root tests without structural breaks. Thus, we are unable to reject the null hypothesis of unit root at the 10% level or better, confirming that the series are at least I(1). The break dates for RGDP intercept and slope are 1987 and 1989, respectively. On the break dates for CAPITAL, the study notes 1988 and 1993 for the intercept and slope, respectively. Lastly, the break dates for intercept and slope of ELECTRICITY are 1989 and 1992 respectively. The periods correspond to the time (17 August 1992) in which the Southern African Development Community (an establishment championed by the biggest economy in Africa and Botswana's largest supplier of electricity-South Africa) was formed.

Table 3. Zivot–Andrews test for unit roots

Variables	Model A		Model B	
	Z-A	Break	Z-A	Break
RGDP	-4.686	1987	-4.141	1989
CAPITAL	-4.726	1988	-4.001	1993
ELECTRICITY	-4.795	1989	-3.566	1992

The critical value for 1% and 5% levels are -5.340, -4.800 and -4.420, -4.800 for Model A and B from Zivot and Andrews (1992). For easy comparism to the ADF test the optimal lag is set to 1. The two models contain deterministic components. The null hypothesis is no stationarity in the presence of endogenous structural break.

The results of the bounds test for cointegration, together with critical values of Pesaran and Pesaran (1997) are reported in Table 4. The bounds test indicates that there is a cointegration relationship. At 10% significance level, we reject null hypothesis of no cointegration, when the RGDP is the dependent variable. However, when CAPITAL and ELECTRICITY are the dependent variables, there is no cointegration. The existence of cointegrating relationship among RGDP, CAPITAL and ELECTRICITY suggests that there must be Granger causality in at least one direction, but it fails to signify the direction of temporal causality among the variables.

Table 4. Bounds tests for cointegration

Dependent Variable	F-Statistics	10% I(0)	10% I(1)	5% I(0)	5% I(1)	1 I %(0)	1% I(1)
RGDP	4.634*	3.182	4.126	3.793	4.855	5.288	6.309
CAPITAL	2.210	3.182	4.126	3.793	4.855	5.288	6.309
ELECTRICITY	1.742	3.182	4.126	3.793	4.855	5.288	6.309

*, **, *** Imply 10%, 5%, and 1% level of significance respectively. The critical values are for the model with intercept but no trend, as contained in case II of Pesaran and Pesaran (1997). The null hypothesis is no cointegration.

In table 5, the study examines short-run and long run Granger causality and the long run estimates. Long run causality is found from ELECTRICITY to RGDP, but with no feedback from RGDP. This unidirectional result is similar to the findings of Odhiambo, (2009a) on Tanzania and Kouakou (2011) on Cote D'Ivoire. According to Nayaran and Prasad (2007), this implies that reducing electricity consumption could lead to a fall in income. The long run estimates of the ARDL reinforce the Granger causality tests by suggesting that ELECTRICTY is positively and significantly associated with RGDP in the long run. In particular, for every 1% increase in ELECTRCITY, there is 1.06% increase in RGDP, at 5% significance level. These results have a lot of significance on the Botswana economy. It implies that the country is highly energy dependent. This is not surprising, as Botswana requires substantial electricity for its diamond mining.

Table 5. Causality and long run estimates

Variable	Granger causality results				Long run estimates		
	ΔRGDP	ΔCAPITAL	ΔELECTRICITY	ECT(-1)	RGDP	CAPITAL	ELECTRICITY
ΔRGDP	-	6.939**	1.778	-1.767*	-	-0.338	1.063**
ΔCAPITAL	8.272**	-	0.878	-	-	-	-
ΔELECTRICITY	2.030	0.542	-	-	-	-	-

For the equation with ΔRGDP as dependent variable, the optimal lag selection is 1, 3 and 3, respectively. The unrestricted VAR is utilised in computing the causality with ΔCAPITAL and ΔELECTRICITY as the dependent variables. In this case the maximum lag is set to 3. Generally, the null hypothesis is no Granger causality. The chi-square statistics are reported for the variables, while the t-statistic is reported for the ECT. *, **, *** Imply 10%, 5%, and 1% level of significance respectively.

The lack of feedback from RGDP may mean that the focus of the economy on the electricity sector has not been adequate and misfit in Botswana. In other words as regular growth of electricity supply is germane in boosting economic output; however, additional income or economic growth does not translate into adequate capital investment in electricity sector, and thus does not stimulate additional electricity consumption. The results on CAPITAL confirm this finding as there is no causality flowing from CAPITAL to ELECTRICITY. The study notes further that in the long run, CAPITAL Granger causes RGDP with a short run feedback. The long run estimates suggest CAPITAL has negative and insignificant impact on RGDP implying that there is somewhat a relationship between CAPITAL and ELECTRICITY. Thus, we interpret this to mean that capital formation will have adequate impact on the economy if there is adequate electricity in the economy.

Table 6. Diagnostics tests

Test Statistics	LM test	F-test
Serial Correlation	CHSQ(1) = 0.064 [0.800]	F (1, 15) = 0.037 [0.850]
Functional Form	CHSQ(1) = 0.233 [0.630]	F(1, 15) = 0.135 [0.718]
Normality	CHSQ(2) = 1.276 [0.528]	N/A
Heteroscedasticity	CHSQ(1) = 1.784 [0.182]	F(1, 24) = 1.768 [0.196]

The study applies a number of diagnostic tests to the ARDL estimates in Table 6. The tests suggest that no autocorrelation in the disturbance of the error term. The RESET test indicates that the model is correctly specified and no functional form problem. The model passes the Jarque-Bera normality tests, signifying that the errors are normally distributed. Moreover, the ARCH test denotes that the errors are homoskedastic and independent of the regressors. Given that neither the CUSUM nor the CUSUMSQ test statistics exceed the bounds of the 5% level of significance, the regression equation appears stable over the period of estimation.

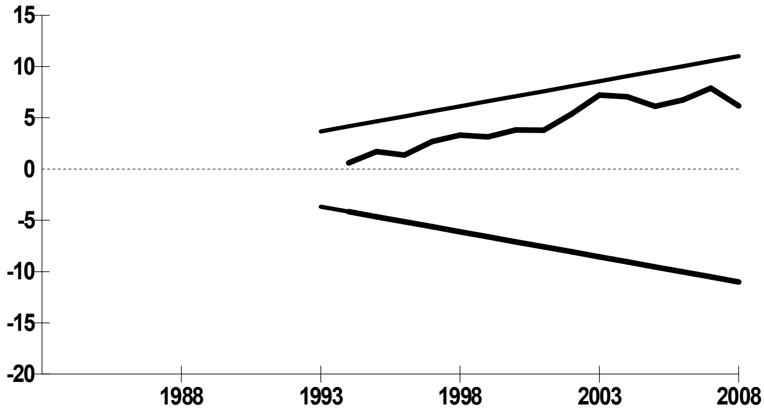

Fig. 2 Plot of Cumulative Sum of Recursive Residuals

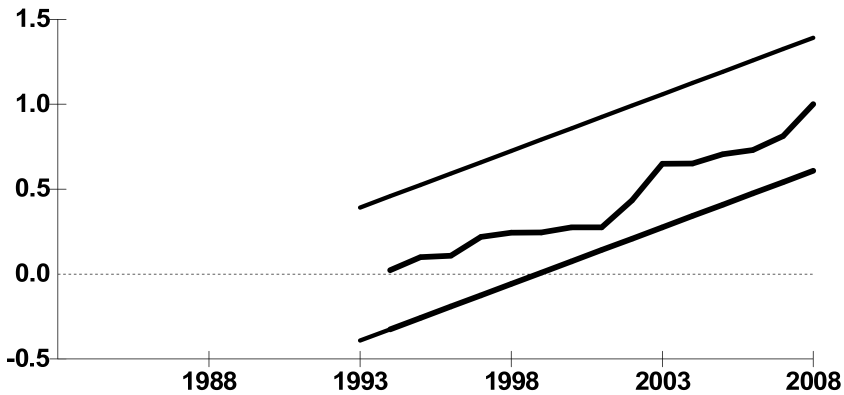

Fig. 3 Plot of Cumulative Sum of Square of Recursive Residuals

Forecasting electricity gap for Vision 2016

In order to investigate whether Botswana is likely to achieve Vision 2016 (conceived in 1997) of 100% electrification by 2016, the study forecasts the electricity gap for the period 2009 to 2016 using exponential smoothing technique in Table 7. Exponential smoothing method is a very popular scheme to produce smoothed and forecasted time series (Pyo and Choi, 2009). Specifically, the study utilises the one parameter (double) technique. This method applies a single smoothing method (using the same parameter) on the level and trend components of the variable and is appropriate for series with a linear trend.

Obviously, from Table 7, electricity situation is likely to worsen if the current trend is sustained. Therefore, Vision 2016 may not be achieved based on the current situation. On the forecasting accuracy we used the one parameter (double) exponential smoothing technique because, of all the five methods of exponential smoothing considered; this method produces the smallest alpha in all cases. In fact, it is within Bowerman and O'Connell (1979) suggested range of 0.01 to 0.30 in the case of ELECTRICITY (at 0.296) and closest to the range in the case of GENERATION (at 0.368). The lower the value of alpha, the less responsive the forecast is to sudden change. As our two values are well below the benchmark value of 0.5, we argue that the forecasts are accurate. In Fig. 4, the study graphically examines how the actual and forecasted series moves together. The forecasted series for ELECTRICTY is ELECTRICTYSM, while GENERATIONSM is the forecast for GENERATION. Evidently, the figure shows that the forecasted figures move in tandem with the actual values.

Table 7. Forecasts of electricity gap, 1997–2016

	ELECTRICITY		GENERATION		GAP
YEAR	ACTUAL	FORECAST	ACTUAL	FORECAST	
1997	958.385		535.480		-45.309
1998	946.372		618.063		-119.022
1999	1033.191		616.134		-137.724
2000	1085.017		607.818		-164.651
2001	1156.209		542.652		-168.969
2002	1130.334		562.063		-10.347
2003	1344.766		583.178		-12.565
2004	1328.015		513.359		-7.019
2005	1371.904		496.452		-18.023
2006	1384.040		524.981		-31.959
2007	1442.064		358.270		-2.682
2008	1483.508		308.674		-59.193
2009		1537.262		299.120	-156.778
2010		1584.278		258.838	-172.084
2011		1631.293		218.557	-397.962
2012		1678.309		178.275	-422.906
2013		1725.324		137.993	-328.309
2014		1772.340		97.712	-417.057
2015		1819.355		57.430	-477.198
2016		1866.371		17.149	-613.557

For GENERATION, the alpha is; single parameter technique, 0.914; one parameter (double) technique, 0.368; Holt-Winters-no seasonal (two parameters), 0.930; Holt-Winters-additive technique, 1.000; and Holt-Winters-multiplicative technique, 1.000. For ELECTRICITY the alpha is; single parameter technique, 0.987; one parameter (double) technique, Holt-Winters-no seasonal (two parameters), 0.550; Holt-Winters-additive technique, 0.610; and Holt-Winters-multiplicative, 0.580.

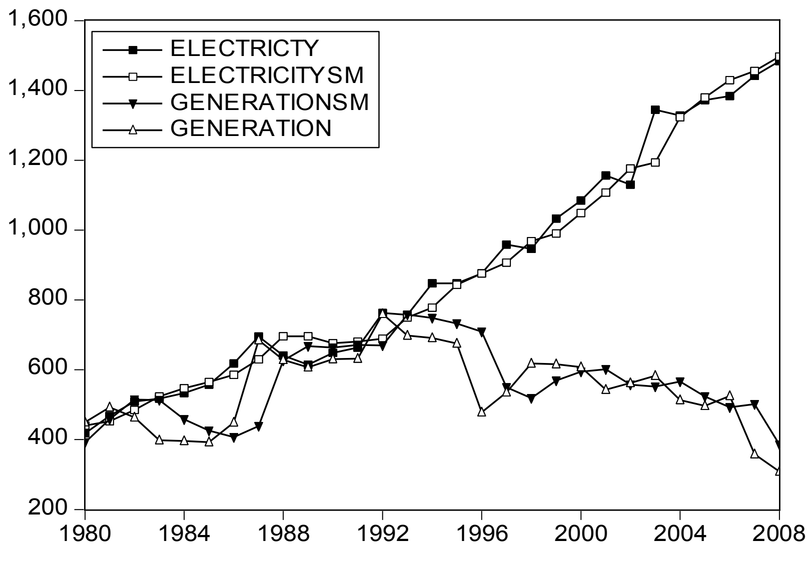

Fig. 4 Actual and forecasts of electricity gap, 1980-2008

6. Conclusion

The study investigates the relationship between electricity consumption per capita and real gross domestic product per capita in Botswana. The study includes capital formation in a trivariate system for the period of 1980 -2008. Choosing Botswana is ideal, as no published study has conducted research on the largest diamond producing country, before now. This is in the face of the country's persistent electricity deficit and large electricity dependence on South Africa. Unlike any previous study on Africa, we provided for structural breaks in testing for unit roots using the Zivot and Andrews (1992) to endogenously determine structural breaks before proceeding to the bound test for cointegration and the Granger causality tests in addition to providing the long run estimates. The results suggest long run causality from electricity consumption to real gross domestic product, but with no feedback from real gross domestic product. This unidirectional causality is in line with of Odhiambo, (2009a) on Tanzania and Kouakou (2011) on Cote D'Ivoire. The long run estimate reinforces the Granger causality tests by indicating that electricity consumption is positively and significantly associated with real gross domestic product in the long run. Summarily, this may be interpreted to mean that Botswana is a highly energy dependent country. This is not surprising as the economy depends on electricity for its mining activities. Thus, improving electricity could improve income generation. Further results suggest that unidirectional causality from capital formation to real gross domestic product, with the coefficient of capital formation being negative and insignificant in the long run. Thus, we interpret this to mean that capital formation will have adequate impact on the economy if there is adequate electricity supply in the economy. Besides, the findings on forecasting suggest that if the current situation is sustained, then the problem of electricity gap is likely to worsen in Botswana. From the foregoing, it is obvious that electricity policy that focuses on securing the long-term supply will naturally spur sustainable growth of economic activities. In this regard, we urge the authorities in Botswana to intensify the issue of diversification of electricity sources and management. Solar energy is described as a viable alternative to other sources of electricity. One additional benefit of solar energy is that it is cheaper to generate locally. Diversification into solar energy will reduce the dependence of Botswana dependence on Eskom. On the issue of electricity management, it is pertinent that the privatisation of BPC should be accelerated, especially in the area of generation in which private generation companies will be allowed in the electricity supply market in Botswana. This will not only provide an avenue for the much-needed private capital in the electricity sector, but also foster competition in the electricity supply market that would allow large consumers to select their own supplier.

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