ELECTRICITY CONSUMPTION IN BOTSWANA: THE ROLE OF FINANCIAL DEVELOPMENT, INDUSTRIALISATION AND URBANIZATION

LIRA P. SEKANTSIT, SAYED TIMUNO**

Abstract: Botswana’s electricity supply is overwhelmed by the growing energy demands with the peak electric power deficits being met through imports. This study seeks to understand the key drivers of this increasing electricity demand. Using the Autoregressive Distributed Lag (ARDL) bounds testing and Error Correction Model (ECM), it examines the role played by financial development, industrialisation and urbanization in Botswana’s energy (or more specifically electricity)-growth nexus between 1981 and 2011. The findings reveal that economic growth, financial development and industrialization positively affect electricity consumption in the short-run and long-run. However, urbanization increases electricity consumption only in the long-term. These finding not only support conservation hypothesis but also imply that policy-makers should take into account the increase in electricity demand arising from financial development, urbanization and industrialisation in energy (electricity) consumption planning in the economy to avoid energy crisis. In addition, policy-makers should search and invests in renewable energy sources such as solar to increase access to cheap energy source.

Keywords: Electricity Consumption, Financial Development, Industrialisation, Urbanization, Cointegration, Botswana.

JEL Classification: C22, Q43, Q48

1. INTRODUCTION

Energy plays a central role in the economic growth and socio-economic development of countries around the world. This is because apart from improving

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socio-economic development, energy acts as a direct and indirect input in the production of goods and services in various sectors of the economy. In light of this, demand for energy continues to increase rapidly around the world. In line with this, most emerging economies and developing countries (including those in Africa) have experienced serious energy (or electricity) deficiency and have been struggling to meet the increasing demand for electricity (see Sekantsi and Motlokoa, 2015; Shahbaz and Lean, 2012; Zaman et al. 2012; Inglesi-Lotz, 2011). Botswana is not an exception to this dilemma.

Since gaining its independence, Botswana experienced rapid economic growth over the last four decades. In real terms, the economy recorded positive growth rate of 8% and 6% in 1981 and 2011, respectively. This robust growth was mainly driven by its energy-dependent mining (diamond) sector, which contributes significantly to government revenue in the country (Waves, 2014 and 2016; United Nations Economic Commission for Africa, 2016 and Kapunda and Moffat, 2016). Despite this remarkable performance, the country suffers from energy shortage due to its underdeveloped energy sector, which fails to generate enough power to meet increasing energy demand. Therefore, the peak power deficits have to be met by imports from Electricity Supply Commission (Eskom) in South Africa, Namibia Power Corporation(Nampower), Zambia Electricity Supply Corporation(ZESCO) and Southern African Power Pool(SAPP). However, the country still experiences load shedding (power black-outs) as a result of power supply shocks in exporting countries. Not only does this negatively affect socioeconomic wellbeing of the citizens and economic activities but also has a potential to undermine country’s growth prospects and the ability to achieve the long term developmental objectives outlined in the country’s Vision 2036. In addition, the country also experienced high rate of urbanisation; with two thirds of the country’s population now living in urban areas and its industrial sector has grown significantly in recent years. The financial sector (especially the banking Sector) also underwent notable and exceptional growth due to financial reforms in recent years (Honde, 2016). These factors not only promote economic growth and improve standard of living but they can also increase pressure on energy demand in the country (Al-Mulali et.al, 2012 and Liu, 2009,ab; Komal and Abbas, 2015 and Kahsai et.al,2012; Sadorsky,2013).

The literature shows that aside from economic growth there are other factors (such as urbanization, industrialization, and financial development) that affect
energy demand in the economy (see Karanfil, 2009; Shahbaz and Lean, 2012). However, the studies that examined energy (or electricity) demand in Botswana namely; Adebola(2011), Amusa and Leshoro(2013), Essah and Efetotse(2014), Efetotse et.al (2015), have not considered how urbanization, industrialization and financial development affect energy (or electricity) demand in Botswana. This calls for more scholarly attention in identifying the factors influencing energy (or more specifically electricity) demand in Botswana in order to guide Government of Botswana, policy makers and other stakeholders in energy sector in the design of effective energy policy to address increasing energy demand in Botswana. Therefore, this paper seeks to understand the key determinants behind the growth of electricity consumption in Botswana by taking into account the role of financial development, industrialisation and urbanization in Botswana’s energy-growth nexus. In this regard, it also contributes to the empirical literature on the drivers of energy consumption in Botswana (beyond what the aforementioned studies have done) and in developing countries in general. In order to investigate this relationship, the paper applies autoregressive distributed lag (ARDL) bounds testing approach to cointegration and estimates an error correction model (ECM) on Botswana’s annual time series data ranging from 1981 to 2011.

The rest of the paper is structured as follows. The next section provides an overview of Botswana’s energy sector. It is followed by a review of the literature on energy (or more specifically electricity) consumption determinants and the methodology. The empirical results are then presented and lastly, the concluding remarks together with recommendations are offered.

2. AN OVERVIEW OF ENERGY SECTOR IN BOTSWANA

Botswana is a small, landlocked country of about two million people with a total land area of approximately 582,000 square kilometers. At independence, Botswana was classified as one of the poorest countries globally (in terms of per capita GDP of approximately $707). Post-independence, the country recorded robust economic growth due to discovery of diamonds, the effective and transparent use of mineral proceeds, good governance practices, political stability,

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7 World Bank Database.
8 It recorded real GDP growth of approximately averaging 5% per year over the past ten years.
and prudent macroeconomic and fiscal management. As a result, it graduated to the ranks of upper-middle income countries. Notwithstanding this, the country still faces other socio-economic challenges of poverty; inequality and graduate unemployment (see UNECA, 2016).

The main energy sources in the country are electricity, fuel wood, liquefied petroleum gas, petrol, diesel, aviation gas and paraffin; with most of these imported largely from South Africa. Despite, possessing the huge natural resources endowment in the form of abundant coal (200 billion tonnes accounting for about 66% of the continent’s coal resources) and sunshine (over 3200 hours at 21MJ per square metres), the country’s energy sector remains underdeveloped and characterized by relatively low access and coverage by international standards. For example, fuel wood continues to be an important energy source with approximately 46% of the households nationally and 77% in rural areas relying on it for cooking. In addition, the electrification rate is reported to be at 49% and as of March 2015, the national access to electricity in the country stood at approximately 73% of the country’s population; with rural access standing at approximately 67% of the population.9 In terms of consumption, more electricity is consumed by the mining sector, followed by commercial sectors and the household sector. Electricity consumption by the government sector remains relatively low compared to that of the above-mentioned sectors (See UNDP and GoB, 2012; UNECA, 2016; Nachmany et al., 2015; Botswana Power Corporation (BPC), 2010, 2011, 2012, 2015).

In the recent past, members of the Southern African Power Pool (SAPP)10 including Botswana have experienced power supply deficit. In Botswana, this has led to persistent load shedding (rolling blackouts) which was aggravated by insufficient domestic power generation due to aging electricity infrastructure and underinvestment in energy infrastructure. In addition, the government’s energy policy has over the years concentrated more on thermal power production due to the country’s vast coal resources. This resulted in a partial neglect of other potential energy sources such as diesel and solar for power generation. Moreover, climate change impacts such as chronic droughts resulting from semi-arid climate

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9 Note that this was based on initial parameters and the 2001 population census.
10 The SAPP is a cooperation of the national electricity companies in Southern Africa under the auspices of the Southern African Development Community (SADC). Therefore, members of SAPP are SADC countries.
conditions and erratic rainfalls have undermined hydropower generation, contributing to supply shortages. Furthermore, the monopoly of the electricity sector by the state-owned Botswana Power Corporation (BPC) has led to lack of competition in the market and inefficiencies in electricity generation, transmission and distribution in the country, which in turn constrained growth and the general development of the sector in the economy. In light of this, the country relies on imports from Eskom, NamPower, ZESCO and the SAPP (with more electricity imported from South Africa) to meet supply shortages (see Promethium Carbon, 2016a and 2016b; UNECA, 2016). On average, between 2005 and 2015, the ratio of imported electricity to total distribution was around 71% (see Table 1).

With electricity shortage recognized as a barrier to economic growth and socioeconomic development in the country, the Government of Botswana (GoB) has in the past few years embarked on an extensive power-sector reforms aimed at meeting the ever increasing demand, improving energy generation and distribution, energy efficiency and conservation to attain self-sufficiently in electricity supply. These reforms include the short term measures of constructing two emergency diesel powered plants; 90 MW at Orapa and 105 MW at Motshelagabedi. In addition, the medium to long term reforms include the refurbishment of Morupule A power plant and the construction of a four unit power station (Morupule B) which is expected to generate 600 MW of electricity. Other reforms include the policy shift from the importation of power to self-sufficiency in power generation and supply. This initiative led to the amendment of the Electricity Supply Act in 2007 to allow the participation of the private sector (i.e independent power producers (IPPs)) in the country’s electricity industry to further augment electricity supply in the economy. To date, BPC and Electricity de France have formed a private renewable power company called BPC Lesedi, which provides renewable(solar) energy products and services to remote and rural areas of the country not connected to the national electricity grid (Promethium Carbon, 2016a and 2016b and Efetotse et al, 2015). In addition, the GoB has has received positive responses from other IPPs to develop two additional units at Morupule B power plant.
Furthermore, the GoB has launched the Rural Electrification Programme which seeks to connect various villages to the national grid and the Rural Electrification Collective Scheme, National Electricity Standard Connection cost and National Electrification Fund which are aimed at addressing issues of high connection costs and assisting households to connect to the national electricity grid at a national standard cost in electrified settlements, villages, towns and cities. The country has also embarked on the review of the National Energy Policy and Electricity Regulatory Framework for consideration by parliament during the 2016/17 financial year. Apart from that, the country is developing Renewable Energy Strategy and Energy Efficiency Strategy with the broad aim of addressing energy demand challenges and to position the country as an energy exporter. Institutionally, Botswana does not have an independent energy regulator. Therefore, the Department of Energy (under the auspices of the Ministry of Mineral Resources, Green Technology and Energy Security) currently acts as an interim energy regulator in the country with additional responsibility to develop energy policies in the country and supervision of BPC. However, as part of the energy sector reform project, the country plans to establish a Botswana Energy Regulatory Authority (BERWA) with
an aim to take-off all responsibilities of energy regulation from the Department of Energy (see Promethium Carbon, 2016a and 2016b).

3. Literature Review

The issue of the relationship between energy (or electricity) consumption and economic growth was initiated by Kraft and Kraft (1978), who concluded that economic growth resulted in increased energy demand in the United States (US) during the period 1947-1974. Following this empirical study, many empirical studies examined the nexus between these two variables and its policy implications in the context of two-way Granger causality. This led to four testable hypotheses, namely; the growth hypothesis, conservation hypothesis, feedback hypothesis and neutrality hypothesis. First, the growth hypothesis states that energy is an input in the production process and therefore energy consumption stimulates economic growth. Among others, the empirical works of Odhiambo (2009a), Narayan and Singh (2007), Altinay and Karagol (2005), Apergis and Payne (2009), Bowden and Payne (2009), Tsani (2010), Wang et al. (2011) found that energy (electricity) consumption increases economic growth. Second, the conservation hypothesis argues that economic growth influences energy consumption such that the more growth the economy experiences, the more energy will be demanded and consumed to support that kind of growth. Thus, energy conservation policies aimed at reducing energy use and waste can be implemented without negatively affecting economic performance (see Gosh, 2002). The empirical work of Kwakwa (2012), Narayan and Smyth (2005), Adom (2011), Mozumder and Marathe (2007), among others, found that economic growth affects energy consumption.

Third, the feedback (bidirectional) hypothesis asserts that energy consumption and economic growth are interrelated and may complement each other. In this case, efficient energy use and energy development policies geared towards increasing electricity generation can positively affect economic growth. Aslan (2014), Odhiambo (2009b), Tang (2008), and Masih and Masih (1997) are some of the empirical studies that provide support for this hypothesis. Finally, the neutrality hypothesis postulates that there is no causal relationship between energy consumption and economic growth. Thus, neither conservative nor expansive policies in relation to energy consumption have any impact on economic growth in the country. This hypothesis received

The empirical studies that examined energy-economic growth nexus failed to reach consensus on the relationship between these variables due to a number of factors including the employed model estimation techniques, problems associated with non-stationarity of data, different data sets, choice of variables, and different country characteristics (see Adom, 2011; Sekantsi and Motlokoa, 2015; Komal and Abbas, 2015, among others). In addition, most studies that examine this relationship have also over-relied on a bivariate causality framework, which may suffer from the omission of variable bias by ignoring other important variables (such as financial development, industrialization and urbanization and specific country characteristics), which determine energy consumption in the economy.

The theoretical link between financial development and energy consumption is well established in the literature. At the household level, a well-developed financial system makes it easier for consumers to save, invest and borrow funds at cheaper costs to purchase energy consumable products such as automobiles, houses, refrigerators, air conditioners, and washing machines. These items normally consume a lot of energy with resultant potential to spur the overall demand for energy in the country. At the industrial level, a sophisticated financial system brings about improvements in financial markets infrastructures, which help entrepreneurs to not only to save and invest but also to access financial capital easily and at lower costs. Through this financial capital, entrepreneurs can either start new businesses or expand their existing businesses by buying and building more plants and factories as well as investing in more and/or advanced machinery and equipment, all of which increase demand for energy. For this purpose, a stock market development serves as a suitable avenue from which entrepreneurs may raise additional financing for businesses in the form of equity aside from debt financing. By availing more funds for investment projects as a result of increased risk diversification, stock markets lead to economic growth and property. This in turn boosts general consumer and business confidence in the economy with resultant increase in demand for energy intensive goods, which obviously increase energy consumption (see Mankiw and Scarth, 2008; Sadorsky, 2010; Islam et al, 2013; Komal and Abbas, 2015 and Chang, 2015).
Aside from increasing energy demand, the literature on the finance–energy nexus also argues that financial development lessens energy consumption through improving efficiency in the use of energy. In particular, investment in research and development (R&D), advancement in technology as well as innovation allow creation of energy efficient products like home appliances, which reduce energy consumption (Coban and Topcu, 2013). In connection with this, technology innovation by local firms emanating from foreign direct investment (FDI) inflows into the economy can reduce energy use in the economy (see Alfaro, et al, 2004, 2006; Bailliu, 2000). This is because some governments can provide financing support and encourage the licensing of sustainable energy technologies and services in an effort to ensure energy efficiency and sustainability in their jurisdictions (Mielnik and Goldemberg, 2002). Apart from financing energy intensive sectors, developed financial institutions can offer financing to renewable energy sector while capital markets can provide debt and equity financing to green renewable energy projects. In this way, financial development can lead to decrease in energy consumption in the economy. In addition; sophisticated financial markets do extend credit for environmentally friendly projects at low financing costs. While some of these projects may be aimed at reducing environmental costs associated with emission of carbon-dioxide into the air and water pollution, they decrease energy use. In light of this, it is obvious that financial development can increase energy consumption through lending capital to the energy industry on one hand. On the other hand, it can reduce energy consumption by acting as an incentive for increased energy substitution. In that respect, the effect of financial development on energy consumption is ambiguous (Dasgupta et al, 2006 and Chang, 2015).

The term industrialization refers to increase in industrial activities mainly emanating from economic growth in the economy. The economic literature has established a direct link between increase in industrial activity and energy demand due to growth in different sectors of the economy. According to this literature, increased industrial activity in the form of large-value manufacturing, which involves the use of heavy and advanced machinery and equipment, require more energy relative to traditional agriculture and basic manufacturing. For instance, industries specializing in petroleum refinement and production of some chemicals and paper usually consume more energy than those in agriculture. In light of this, industrialization is usually associated with increase in energy consumption in the
economy. Therefore, industrialized economies demand more energy than less industrialized economies (see Sadorsky, 2013 and 2014).

According Chace and Walsh (2006) and Wang (2014), urbanization relates to structural changes in the economy in the form of physical growth of urban areas resulting from rural migration and sub-urban concentration into cities or industrial areas. It is measured as the ratio of urban population to the total population. The literature has established several ways through which urbanization can impact upon demand for energy in the economy. First, urbanization can affect energy consumption in the economy through its impact on production process. By availing more labour that can participate in the production of goods and services, it increases economic activities in urban areas and brings about economies of scale in production. In this regard, production methods shifts from those that are less energy intensive to those that are more energy intensive with resultant increase in overall energy consumption. It also accelerates fuel switching from conventional energy sources such as biomass, paraffin and oil to centralized energy sources like electricity. In addition, the surge in production activities in urban areas may further increase demand for energy through growth in the informal economy and demand for more infrastructure such as road, buildings and so on. Second, urbanization increases energy consumption through increased mobility and motorized traffic in urban areas as well as transportation of raw materials and finished goods to and from the urban areas, all of which demand more energy. Lastly, apart from changing the production pattern of firms, which consequently increases energy demand, urbanization also transforms society's economic structure and lifestyle. By so doing, it affects energy consumption by changing the consumption pattern of urban dwellers to energy intensive products (such as refrigerators, air conditioners, automobiles, laptops) as they become richer (see Sadorsky, 2013 and 2014).

Empirically, there are several studies that explored the link between energy consumption and economic growth by also incorporating other variables such as financial development, industrialization and urbanization. Poumanyvong and Kaneko (2010) used panel data techniques examine the effect of income, urbanization, industrialization and population on energy use in a sample of 99 countries during the period 1975-2005. The findings suggested that the effect of urbanization on energy use varies across the stages of development of countries and urbanization decreases energy use in the low-income group, while it increases
energy use in the middle- and high-income groups. In addition, the results also suggested that industrialization impacts positively on energy consumption. However, its effect is only statistically significant in low and middle income groups. Shahbaz and Lean (2012) also assessed the relationship between energy consumption, economic growth financial development, industrialization and urbanization in Tunisia. Applying ARDL bounds testing and Granger causality tests on data for the period 1971 to 2008, the study confirmed the existence of cointegration among these variables in Tunisia and that in the long-run, ceteris paribus, a 1% increase in economic growth and financial development spur energy consumption by 0.5% and 0.14%, respectively, while 0.21% (and 0.9%) increase in energy consumption is found to be due to industrialization (and urbanization), respectively, holding other variables constant. In the short-term, the impact of financial development and industrialization on energy consumption was also found to be positive and statistically significant while urbanization had insignificant positive effect on energy demand in Tunisia.

Sardosky (2014) investigated the impact of income, urbanization and industrialisation on energy consumption in a sample of 18 emerging markets economies (including South Africa) during the period 1971-2008. Applying different panel data approaches, the results revealed that income increases energy consumption in both the long-run and short-run in these countries. In addition, the results showed that urbanization decreases energy consumption in the long-term while industrialization increases it during the same time horizon. In another study, Islam et al (2013) applied ARDL bounds testing and vector error correction model (VECM) on data for period 1971-2009 to examine the link between energy consumption, financial development, economic growth and population in Malaysia. Their results provided evidence that, ceteris paribus, a 1% increase in economic growth and financial development, respectively, raise energy consumption by 0.86% and 0.07%, in the long-run on the one hand. On the other hand, a 1% rise in economic growth and financial development, respectively, increase energy consumption by 0.7% and 0.12% in the short term. However, the effect of population on energy consumption is only found to have positive in the long-run; with 1% increase in population size increasing energy consumption by 0.39%.

Salman and Atya (2014) employed Johansen cointegration test, error correction model and Granger causality to assess the causal relationship between
energy consumption, financial development and economic growth in North African countries (namely Algeria, Egypt and Tunisia) over the period 1980-2010. The empirical results indicated positive relationship between financial development and energy consumption in Algeria and Egypt but negative relationship between these two variables in Tunisia. Komal and Abbas (2015) also explored the finance-growth-energy nexus in Pakistan during the period 1972-2012. By using the system Generalized Method of Moments (GMM) estimation technique, study captures the effect of financial development on energy consumption by using economic growth as an intermittent variable and includes energy prices and urbanization. The results revealed that financial development significantly increase energy consumption through economic growth channel whereas, the economic growth and urbanization significantly increase energy consumption in Pakistan. The other study by Abosedra et.al(2015) used ARDL bounds testing and VECM to examine the relationship between energy consumption, financial development, and economic growth in Lebanon for the period 2000M7-2010M12. The results not only provide empirical evidence of cointegration between these variables but also establish that energy consumption and financial development significantly increase economic growth both in the long-run and short. On the other hand, financial development and economic growth also further increase energy consumption both in the long-run and short-run in Lebanon. In a recent study, Sekantsi et.al (2016) examined the role of financial development, industrialisation, and urbanisation in Lesotho’s energy-growth nexus between 1973 and 2012. The findings from the cointegration analysis reveal that economic growth, financial development, and industrialisation are positively related to electricity consumption in the long-run. However, urbanization is found to have no significant effect on electricity consumption. Furthermore, regulation has also impacted positively on electricity demand in Lesotho.

In light of this literature review, it is obvious that there are other factors (such as financial development, industrialisation, and urbanization) in addition to economic growth that do impact upon energy (electricity consumption). However, in the context of Botswana, the few existing studies namely; Adebola(2011), Essah and Efetotse(2014), Efetotse et.al(2015) that examined energy(electricity)-growth nexus have not taken these other factors into account though they may have important implications for the underlying energy consumption given the level of economic development that Botswana has achieved so far. Therefore, this study
incorporates these variables to better understand the drivers of electricity consumption in Botswana.

4. ECONOMETRIC METHODOLOGY

This study adopts the basic framework for energy (or more specifically electricity) demand (consumption) used by Salman and Atya (2014) and Shahbaz and Lean (2012), specified as follows:

\[ \ln(\text{EC})_t = \beta_0 + \beta_1 \ln(\text{GDP})_t + \beta_2 \ln(\text{FD})_t + \beta_3 \ln(\text{IND})_t + \beta_4 \ln(\text{URB})_t + \varepsilon_t \] (1)

where \( \ln(\text{EC})_t \), \( \ln(\text{GDP})_t \), \( \ln(\text{FD})_t \), \( \ln(\text{IND})_t \) and \( \ln(\text{URB})_t \) denote the natural logarithms of electric power consumption, economic growth, financial development, industrialization and urbanization, respectively. \( t \) is the time period, \( \beta \)'s are long-run parameters to be estimated, \( \varepsilon_t \) is the random error term. According to the reviewed literature on energy consumption, \( \beta_1 \) captures the effect of economic growth on energy (electricity) consumption, holding other variables constant, which is expected to either increase if the production process is energy intensive or decrease if it occurs in an efficient manner that conserves energy (see Islam et al., 2013). The marginal propensity for financial development, \( \beta_2 \), is expected to be either negative or positive while the marginal effects of industrialisation, \( \beta_3 \), and that of urbanization, \( \beta_4 \) are both expected to be positive.

In building the model for electricity consumption in Botswana, this study employs ARDL bounds testing approach to cointegration and error correction model based on ARDL procedure developed by Pesaran and Shin (1999) and advanced by Pesaran et al. (2001). An ARDL bound testing is preferred to alternative techniques such as the maximum likelihood procedure (Johansen and Juselius, 1990) and the two-step procedure (Engle and Granger, 1987) on account of the following advantages. First, it is applicable irrespective of whether the level variables being tested are integrated of order zero or one, i.e. they may be either I(0) or I(1). Second, it produces robust results even in small samples studies. Third, this procedure has finite-sample critical values as opposed to other cointegration approaches for which the distribution of the test statistic may be unknown in finite samples. Narayan (2005) develops a set of sample-specific critical value bounds for the sample sizes ranging from 30 to 80 using the same
approach and GAUSS code used by Pesaran et al. (2001) in generating the asymptotic values. Furthermore, it provides unbiased estimates of the long-run model and valid t-statistics even in the presence of endogenous regressors.

To implement the bounds test procedure, a conditional ARDL model is specified as follows:

$$
\Delta \ln(EC)_t = \alpha_0 + \sum_{i=1}^{P} \beta_i \Delta \ln(EC)_{t-i} + \sum_{i=0}^{q} \delta_i \Delta \ln(GDP)_{t-i} + \sum_{i=0}^{q} \varphi_i \Delta \ln(FD)_{t-i} + 
\sum_{i=0}^{q} \theta_i \Delta \ln(IND)_{t-i} + \sum_{i=0}^{q} \gamma_i \Delta \ln(URB)_{t-i} + \pi_1 \ln(GDP)_{t-1} + \pi_2 \ln(FD)_{t-1} + \pi_3 \ln(IND)_{t-1} + \pi_4 \ln(URB)_{t-1} + \varepsilon_t \quad (2)
$$

where all variables are as defined as previously, $\Delta$ is the first difference operator, $p$ and $q$ are the lag lengths, $\alpha_0$ is the drift component and $\varepsilon_t$ are random error terms. In the same manner, taking each of the other variables in equation (2) as dependent variables, other equations can be estimated.

In this framework, the long-run relationship between the concerned variables is assessed by testing the null hypothesis; $H_0: \pi_1 = \pi_2 = \pi_3 = \pi_4 = 0$ against the alternative hypothesis; $H_0: \pi_1 \neq \pi_2 \neq \pi_3 \neq \pi_4 = 0$. The computed $F$-statistic derived from this test is compared with two sets of critical values (lower and upper bound values) for a given level of significance reported in Pesaran et al. (2001) and Nayaran(2005) for large samples and small sample sizes, respectively. The lower bound values assume that all variables in ARDL model are I(0) while the upper bound values assume that the variables are I(1). Therefore, if the computed $F$-statistic is less than the lower bound value, the null hypothesis of no cointegration cannot be rejected. On the other, if the computed $F$-statistic exceeds the upper bound value, the null hypothesis of no cointegration is rejected and it is concluded that the variables are cointegrated. Nonetheless, if the computed $F$-statistic statistic lies between the two critical bound values, test becomes inconclusive.

Having established cointegration between the variables of interest, the long-run and error correction models are estimated using ARDL framework as follows:
\[
\ln(EC)_t = \alpha_0 + \sum_{i=1}^{m} \varphi_1 \ln(EC)_{t-i} + \sum_{i=0}^{n} \varphi_2 \ln(GDP)_{t-i} + \sum_{i=0}^{z} \varphi_3 \ln(FD)_{t-i} \\
+ \sum_{i=0}^{q} \varphi_4 \ln(IND)_{t-i} + \sum_{i=0}^{r} \varphi_5 \ln(URB)_{t-i} + \mu_t (3)
\]

\[
\Delta \ln(EC)_t = \alpha_0 + \sum_{i=1}^{m} \vartheta_1 \Delta \ln(EC)_{t-i} + \sum_{i=0}^{n} \vartheta_2 \Delta \ln(GDP)_{t-i} + \sum_{i=0}^{z} \vartheta_3 \Delta \ln(FD)_{t-i} \\
+ \sum_{i=0}^{q} \vartheta_4 \Delta \ln(IND)_{t-i} + \sum_{i=0}^{r} \vartheta_5 \Delta \ln(FD)_{t-i} + \vartheta_6 \text{ECT}_{t-1} + \varepsilon_t (4)
\]

where all variables are as previously defined, \( \mu_t \) and \( \varepsilon_t \) are random error terms and \( \varphi \)'s and \( \vartheta \)'s are the parameters to be estimated, \( m, n, z, q \) and \( r \) are the maximum lag lengths\(^\text{11} \) and \( \vartheta_6 \) is the coefficient of the lagged error correction term (ECT\( t-1 \)), which measures the speed of adjustment to long-run equilibrium following a shock to the system.

**5. **DATA AND EMPIRICAL RESULTS

This paper employs annual time series data for Botswana covering the period 1981-2011. The choice of this sample was dictated by data availability. The data on electric power consumption (measured in kWh per capita), economic growth (measured by real gross domestic product (GDP) per capita), financial development (measured by domestic credit to private sector as a share of GDP), industrialization (measured as a ratio of industrial value-added to GDP), and urbanization (proxied as a share of urban population to total population) was obtained from the World World Bank Development Indicators (January 2015).

\(^{11}\) The maximum lag lengths are normally selected by means of information criteria such as Akaike information criterion (AIC), Schwarz information criterion (SIC) and Hannan-Quinn information criterion (HQ).
As mentioned earlier, the bounds testing procedure can be applied regardless of whether the underlying regressors are I(1), I(0) or mutually cointegrated. However, it is still necessary to pretest the variables for unit roots in order to ensure that none of the variables is integrated of order 2 or greater, which would otherwise invalidate the procedure. Therefore, prior to application of this procedure, the paper undertakes unit root test by employing the standard Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Table 1 reports the results of the ADF and PP unit root tests both in levels and first differences. The ADF and PP tests results indicate that electricity consumption, economic growth, financial development, industrialization and urbanization are integrated of order one or $I(1)$. In light of this, ARDL bounds testing technique to cointegration can therefore be applied.

Table 2 ADF and PP Unit Root Test Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADF Test</th>
<th>PP Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
<td>First Differences</td>
</tr>
<tr>
<td>ln(EC)</td>
<td>-0.7552</td>
<td>-5.6599*</td>
</tr>
<tr>
<td></td>
<td>(0.8172)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>ln(GDP)</td>
<td>-2.3806</td>
<td>-4.4311*</td>
</tr>
<tr>
<td></td>
<td>(0.1554)</td>
<td>(0.0015)</td>
</tr>
<tr>
<td>ln(FD)</td>
<td>-0.9955</td>
<td>-3.3048**</td>
</tr>
<tr>
<td></td>
<td>(0.7414)</td>
<td>(0.0255)</td>
</tr>
<tr>
<td>ln (IND)</td>
<td>-1.8455</td>
<td>-4.1188*</td>
</tr>
<tr>
<td></td>
<td>(0.3521)</td>
<td>(0.0035)</td>
</tr>
<tr>
<td>ln (URB)</td>
<td>-2.3164</td>
<td>-6.7293*</td>
</tr>
<tr>
<td></td>
<td>(0.4130)</td>
<td>(0.0000)</td>
</tr>
</tbody>
</table>

Note: *, **, *** denote the level of statistical significance at 1%, 5% and 10%, respectively. The values in parentheses are the probability values.

Table 3 Bounds Testing to Cointegration Results

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>Critical value bounds of the F-statistic: restricted intercept and no trend</th>
<th>Evidence of Cointegration?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>99%</td>
<td>95%</td>
</tr>
<tr>
<td>$k = 4$</td>
<td>I(0)</td>
<td>I(1)</td>
</tr>
<tr>
<td></td>
<td>6.081*</td>
<td>4.280</td>
</tr>
</tbody>
</table>

Note: 1) Critical values are extracted from Narayan (2005); $k$ is the number of regressors and 2) * denotes the level of statistical significance at 1%.
Table 2 sets out the results of ARDL bounds testing procedure to cointegration between electricity consumption and its determinants. Using Schwarz information criterion (SIC) for selection of the optimal lag length12, results indicate that the null hypothesis of no cointegration is rejected because the calculated F-statistic on the joint significance of the lagged levels of the variables, \( F_{cal} = 6.081 \), exceeds the upper bound critical value at either 1% or 5% levels of significance. Therefore, these results not only provide strong evidence of the existence of long-run steady state relationship between electricity consumption and its covariates but also that economic growth, financial development, industrialization and urbanization are long-run determinants of electricity consumption in Botswana.

Having established cointegration between the variables, the next step in the analysis involves the estimation of long-run elasticities for the existing relationship. Table 3 reports long-run elasticities of electricity consumption with respect to economic growth, financial development, industrialization and urbanization. The results indicate that all estimated long-run elasticities not only have the correct signs (positive) but they are also statistically significant either at 1% or 10% levels of significance. In this regard, their values are consistent with the predictions conceived by economic theory in relation to energy consumption. In particular, the elasticity of electricity consumption with respect to economic growth is positive and statistically significant at either 1% or 10% significance levels. This implies that, ceteris paribus, a 1% increase in economic growth raises electricity demand by 0.4%. This finding is consistent with that of Komal and Abbas (2015), Altinay and Karagol (2005), Shahbaz and Lean (2012), Aqeel and Butt (2001) as well as Adebola (2011) and Amusa and Leshoro (2013) for the case of Botswana. In the same manner, the coefficient of financial development, 0.1026, is also positive and statistically significant at 10% level of significance and it implies that, holding other things constant, a 1% increase in domestic credit to the private sector (financial development) spurs electricity demand directly or indirectly by about 0.1%. This is pertinent given that a well-developed financial sector in the economy provides cheap credit to households and businesses, which raises energy

---

12 The optimal lag length was found to be 2.
demand through increased investment and business activities as well as use of energy-intensive equipment and machines by consumers. This result is in line with the findings of Sadorsky (2010, 2011), Islam et al (2013), Shahbaz and Lean (2012) and Komal and Abbas (2015), among others.

Table 4 Estimated Long-run Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>T-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln(GDP) )</td>
<td>0.4016*</td>
<td>2.9353(0.0085)</td>
</tr>
<tr>
<td>( \ln(FD) )</td>
<td>0.1026***</td>
<td>1.9786(0.0625)</td>
</tr>
<tr>
<td>( \ln(IND) )</td>
<td>0.5860*</td>
<td>3.7689(0.0013)</td>
</tr>
<tr>
<td>( \ln(URB) )</td>
<td>0.2807*</td>
<td>3.1166(0.0057)</td>
</tr>
</tbody>
</table>

Note: Dependent variable = \( \ln(EC) \). *, ** and *** denote the level of statistical significance at 1%, 5%, and 10%, respectively. The values in parentheses are the probability values.

In addition, the marginal effect of electricity consumption with respect to industrial value-added of 0.586 is also positive and statistically significant at either 1% or 5% significance levels. This suggests, holding other things constant, a 1% rise in industrial value-added increases electricity intensity by approximately 0.6% in the long-run. Aside from its consistency with the empirical findings of Shahbaz and Lean (2012) and Sadorsky (2013, 2014), this result is pertinent for Botswana as the country has huge industrial sector (including mining sector and high-valued manufacturing), which demands and consumes more energy (electricity). Lastly, the urbanisation coefficient of 0.28 is positive and statistically significant at either 1% or 5% significance levels and it implies, ceteris paribus, a 1% increase in urbanization increases electricity intensity by approximately 0.3% in the long-run in Botswana. Again, this finding is also relevant for the case of Botswana because the country experienced tremendous urban migration over the past decades with two thirds of the country’s population now living in urban areas. On one hand, this empirical evidence is in accordance with the findings of Shahbaz and Lean (2012), Liu (2009), Islam et.al (2013) Poumanyvong et.al (2012), among others. On the other hand, it contrasts with the finding of Sadorsky (2014) who found that urbanisation decreases energy consumption in a sample of 18 emerging markets economies (including South Africa).
Table 5 Short-run Results and the Diagnostic tests

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Coefficients</th>
<th>T-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ECT(-1)$</td>
<td>-0.9028*</td>
<td>-5.6379(0.0000)</td>
</tr>
<tr>
<td>$d(ln \ (GDP))$</td>
<td>0.2750*</td>
<td>3.1424(0.0054)</td>
</tr>
<tr>
<td>$d(ln \ (FD))$</td>
<td>0.1245**</td>
<td>2.3939(0.0271)</td>
</tr>
<tr>
<td>$d(ln \ (IND))$</td>
<td>0.2725**</td>
<td>2.2944(0.0333)</td>
</tr>
<tr>
<td>$d(ln \ (IND(-1))$</td>
<td>0.2269**</td>
<td>2.1038(0.0489)</td>
</tr>
<tr>
<td>$d(ln \ (URB))$</td>
<td>0.2015</td>
<td>1.0301(0.3159)</td>
</tr>
<tr>
<td>$c$</td>
<td>5.0297*</td>
<td>5.6597(0.0000)</td>
</tr>
</tbody>
</table>

Part B: Diagnostic Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Statistic</th>
<th>Probability Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-squared</td>
<td>0.9912</td>
<td>-</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.9871</td>
<td>-</td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>3.7597</td>
<td>0.1526</td>
</tr>
<tr>
<td>Breusch-Godfrey-LM test</td>
<td>1.5972</td>
<td>0.2063</td>
</tr>
<tr>
<td>BPG</td>
<td>11.4112</td>
<td>0.2486</td>
</tr>
<tr>
<td>Heteroskedasticity Test</td>
<td>0.2425</td>
<td>0.6284</td>
</tr>
<tr>
<td>Ramsey-RESET Test</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Dependent variable = $d(ln(EC))$. *, ** and *** denote the level of statistical significance at 1%, 5%, and 10%, respectively. The values in parentheses are the probability values.

The selected model is ARDL (1, 0, 0, 2, 0)

Table 4 reports the short-run dynamics of the relationship between electricity consumption and its determinants together with the associated diagnostic tests. Consistent with the long-run results, the estimates of all short-run elasticities, with the exception of that of urbanization, are not only positive but also highly significant. Specifically, the positive short-term elasticity of electricity consumption with respect to economic growth (0.275), is statistically significant and close to its long-term value. It implies that a 1% increase in economic growth spurs electricity demand by approximately 0.3%. The same elasticity with respect to financial development, which is also statistically significant and almost the same as its long-run value, suggests that a 1% increase in financial development raises electricity demand increases by approximately 0.12% in the short-run. Despite remaining positive and statistically significant like other elasticities, the short-term elasticity of electricity consumption with respect to industrialisation (0.273) is smaller than its long-run value (0.586), which indicates that over time electricity demand becomes higher in
Botswana as the economy continues to industrialise. However, consistent with the finding of Islam et.al (2013) the elasticity of energy consumption with respect to urbanisation is positive but statistically insignificant perhaps due to longer time dynamic interaction of population with macroeconomic variables.

The coefficient of the lagged error correction term (ECT_{t-1}) not only has the correct sign (negative) but it is also statistically significant at 1\% level of significance. This value confirms the integrity of the estimated long-run relationship (Bannerjee et al, 1998) and ensures the attainment of long-run equilibrium following a shock to the system. It implies that about 90\% of the disequilibrium of electricity consumption adjusts back to equilibrium in the current year following a shock in the previous year in Botswana. The estimated model is also congruent with the data and passes all specification tests with respect to serial correlation, non-normality of residuals and heteroskedasticity. Specifically, the Jacque Bera(JB), BPG Heteroskedasticity and Breusch-Godfrey-LM tests not only fail to reject the null hypotheses of normality of errors, homoskedasticity and no serial correlation, respectively. Therefore, the residuals are white noise and serially uncorrected. In addition, Ramsey’s reset test suggests that the model is well-specified. Furthermore, the short-run model stability, investigated by the CUSUM and CUSUMQ tests (reported in the appendices) on the recursive residuals, shows that the values fall within the 5\% critical bands and this suggests that the parameters of the estimated model are stable over the sample period.

6. CONCLUSION AND POLICY IMPLICATIONS

Botswana’s electricity supply is threatened by the growing energy (electricity) demands, with the peak electric power deficits being met by imports from neighbouring countries; largely South Africa. This paper seeks to understand the key drivers of electricity consumption in Botswana by examining the role played by financial development, industrialization and urbanization in Botswana’s energy-growth nexus over the period 1981-2011. Using the ARDL bounds testing

\footnote{In addition, the Q-statistics and correlogram of squared residuals are also found to be statistically insignificant, which provides more evidence that the residuals in the estimated model are not only serially uncorrected but also homoscedastic.}
approach to cointegration and the associated error correction model (ECM), the results not only confirm cointegration among these series but also reveal that economic growth, financial development, industrialization increase electricity consumption both in the short-run and long-run in Botswana. However, urbanization positively affects electricity consumption in the only in the long-term.

The empirical finding that economic growth increases electricity consumption supports energy conservation policies. Therefore, various energy conservation measures aimed at reducing electricity consumption and waste in Botswana may not have a negative impact on economic growth. The empirical evidence that financial development spurs electricity consumption implies that a fairly developed financial sector in Botswana provides cheap credit to households, businesses and industrial sector, all of which increase demand for electricity due to increased investment and business activities as well as use of energy-intensive equipment and machines by households. In light of this, it is important for policy-makers in Botswana to take into account the increase in electricity consumption resulting from financial development at the time of electricity consumption planning to avoid energy crisis in the economy because failure to do so may result in underestimation of the country’s energy demand at the detriment of sustainable economic growth. In addition, the GoB should consider the role that financial sector plays to finance entrepreneurial projects and research and development (R&D) geared towards innovating and promoting electricity (or more broadly energy) savings technologies and products. Not only will this reduce overall energy consumption but it will also accelerate economic growth through increases in business activities.

Furthermore, the empirical evidence that industrialization increases electricity consumption in Botswana implies that any industrial policy aimed at increasing industrialization spurs electricity demand. It further suggests that urbanization is likely to increase the country’s electricity demand even more in the future. Therefore, it is necessary and prudent for the economy to ensure efficient use of available electricity resources and to upgrade the capacity of the existing electricity (or more broadly energy) facilities to keep electricity production in tandem with growing electricity demand. Moreover, the government should allow more private investments in renewable energy to increase access to cheap energy (or electricity).
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REFERENCES


Appendices

Appendix 1: The Plot of Cumulative Sum of Recursive Residuals (CUSUM)

Appendix 2: The Plot of CUSUM of Squares for Stability of the Model