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Co-integration between Electricity Supply and Economic Growth in South Africa

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ABSTRACT

This study probes the short and long run relationship between economic growth, electricity supply, trade openness, electricity prices, employment and capital in South Africa within a multivariate framework. The autoregressive distributed lag bound testing was employed to establish the long run relationship between these variables using data for the period between 1985 and 2014. Major findings of the study include that economic growth, electricity supply, trade openness, electricity prices, employment and capital are co-integrated. Overall, the paper suggests that efficient planning and increased investments in electricity supply industry infrastructure is of essence to solve the problem of electricity supply as this would force the sustainable economic growth in South Africa.

Keywords: Electricity Supply, Economic Growth, South Africa
JEL Classifications: O13, Q43

1. INTRODUCTION

Electricity is a vital form of energy and therefore electricity supply security is crucial to ensure the continued supply of electricity from a well-functioning industrial process. Digital technologies and modern economies are all dependent on a guaranteed supply of dependable, reliable and efficient supply of electricity. Ellahai (2011) stated that the industrial sector is the engine of economic growth and the performance of an industrial sector depends on a sustained and efficient electricity supply. However, the electricity supply and economic growth relation has not been examined in South Africa.

The electricity supply industry has for years been dominated by Eskom. In the mid-1990s, Eskom implemented a rapid electrification programme which got 2.8 million connected between 1994 and 1999. This led to electricity demand increasing by a large margin. In 2008, the electricity supply could not keep up with the increasing electricity demand and the country started to experience electricity power outages.

South Africa is presently facing a serious electricity crisis. In 2013, the electricity supply reserve margins dropped badly and led to the first experience of power outages since 2008 in 2014 March (Eskom, 2014). The electricity supply industry has been revolving between stages one and two of loading shedding in 2015. This stages indicate the amount of electricity to be saved. For instance, up to 1000 MW for stage one and up to 2000 MW for stage two of electricity that needs to be shed. This is on account that despite the high increase in economic growth and electricity consumption, no worthwhile measures were taken to install new capacity for electricity generation. Electricity shortages have led to a fall in the production of the major sectors of the economy such as industrial, commercial and mining industries.

The persistence of these power outages calls for consideration of the disharmony between electricity supply and economic growth in South Africa. The previous studies were limited to electricity consumption and economic growth (Inglesi-Lotz et al., 2013; Odhiambo, 2009). To the best of the researcher's knowledge, there are no papers that focused on electricity supply and economic growth in South Africa. This gap is served to be filled in this paper. The paper further includes employment, capital, electricity prices and trade openness as the intermittent variables to form a multivariate framework. This fills the void of the previous researchers which only applied bivariate framework.

1.1. Statement of the Problem

Since democratization of the South Africa in 1994, the economy underwent significant structural changes. Among these structural changes was electrification for the poor rural areas. During the apartheid era, about two-thirds of the nation lacked access to electricity and hence, provision for electricity to everyone was considered a crucial part of the economic development, post 1994. Since then economic growth and the demand for electricity in South Africa have been increasing at a faster rate. The electricity supply did not increase proportionally to the increase in the consumption of electricity.

Figure 1 shows the growth rates in the electricity supply and consumption for the period between 1981 and 2011. It can be viewed that electricity consumption has been steadily increasing throughout the period. The country has been experiencing unstable electricity generation (Figure 1). From 2006 the electricity supply shows a declining trend up to 2008 where it was very close to electricity consumption, leaving the utility with small reserves. This led to the rationing of electricity in 2008 because the imbalance between electricity supply and consumption nearly led to breakage in the power generators.

In responding to the high increase in the demand for electricity, the electricity utility planned to build new power stations and put back in use the ones which were mothballed. But unfortunately the plan for investment in these power stations was late and in 2008, the existing power stations were already unable to supply enough electricity. The demand for electricity was such that it nearly damaged the power generating circuit and the electricity supply utility had to resort to load shedding. The imbalance between electricity supply and demand led to industrial sectors cutting down on production and as a result led to a downturn in economic growth. It also led to an increase in electricity prices which had a negative effect on individual and private sectors' budgets.

It is against this background that this study is designed to investigate the long term relationship between economic growth and electricity supply. The additional variables such as electricity prices, trade openness, capital and employment were included as intermittent variables to form a multivariate framework following the work of Khan et al. (2012), Asafu-Adjaye (2000) and Ghosh (2009), Khan et al. (2012) studied the relationship between electricity consumption and economic growth by incorporating trade openness, capital and labor in their model to form a multivariate model. Their study showed that trade openness, labor and capital stimulate economic growth. The model used by Khan et al. (2012) differs from the one used in the research because in this research electricity supply is considered instead of electricity consumption. The literature has proven that very few studies have been completed on the supply side of electricity and this is one of the reasons this current study considers the supply side to add to the literature review following Ghosh (2009).

1.2. Objectives of the Study

The purpose of this paper is to determine the long term relationship between economic growth, electricity supply, electricity prices, trade openness, employment and capital formation. This study intends to:

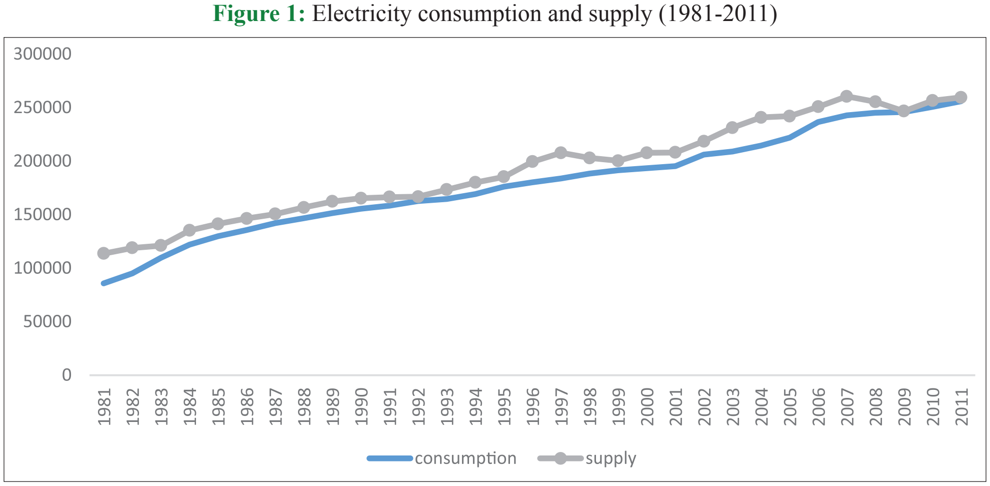
1. Find the impact of electricity prices and trade openness on economic growth and electricity supply
2. Examine the impact of employment and capital formation on economic growth and electricity supply
3. Explore policy measures which will increase electricity supply based on the research findings.

The reminder of the paper is structures as follows: Section 2 will present the literature review followed by Section 3 which will focus on the research methodology. Section 4 will discuss the findings of the research while conclusion will be outlined in the last section.

2. LITERATURE REVIEW

Energy is regarded by Ghosh (2002) as a building block of economic growth. It has a direct positive impact on livelihood and it is an infrastructural input in socio-economic development

Figure 1: Electricity consumption and supply (1981-2011)



Source: Author's own calculations

(Saleheen et al., 2012). Energy economists believe that energy is the main driver of other factors of production and it is helpful for the manufacturing of goods into final products (Lee et al., 2008). Lee et al. (2008) further stated that energy can be used as a substitute for other factors of production such as labor, for instance. It is reasonable to accept that energy is a value-creating production input which is mostly determined by the increasing usage of energy. Therefore, failure to provide energy to meet demand can lead to a decrease in the productivity of an economy. One of the major sources of energy in the modern day is electricity. Electricity is a major source of energy and it is useful in meeting the needs of households and industrial consumers (Salehen et al., 2012). It adds more value to capital (Salehen et al., 2012) and labor (Ghosh, 2009). It also promotes international trade (Samuel and Lionel, 2013). This is because the efficient supply of electricity is enhanced by technology, and developing countries are encouraged to import high technological inputs into generation from developed countries. Therefore, sufficient and efficient supply of electricity can lead to lower poverty levels and boost economic growth (Morimoto and Hope, 2004). However, it can also be derived that economic growth can be improved by boosting electricity consumption.

There a number of studies that have sought to investigate the relationship between economic growth and energy consumption (Kraft and Kraft, 1978; Saidi and Hammami, 2014; Tugcu et al., 2012; Aslan and Oscal, 2013; Vidyarthi, 2013; Wolde-Rufael, 2010; Yuan et al., 2008). These studies retained different results which could be attributable to different models (autoregressive distributed lag (ARDL) models, Johansen co-integration test) and different methodologies (bivariate, trivariate and multi-variate frameworks).

Saidi and Hammami (2014) conducted a bivariate study to assess the link between energy consumption and economic growth using Johansen co-integration technique. The results found that there is a long run relationship between energy consumption and economic growth. Vidyarthi (2013) modified the model by including the carbon emission into the model to from a trivariate framework and also found that energy consumption and economic growth are co-integrated. Masih and Masih (1998) and Hondroyiannis et al. (2012) used energy price as an additional variable and confirmed a long run relationship between energy consumption and economic growth. The multivariate studies were conducted by Wold-Rufael (2010), Lee (2004), Shahibuzzaman and Alam (2012), and Lee and Chang (2008) who added labor and capital as the intermittent variables. Their results also suggested the existence of long run relationship between energy consumption and economic growth. Other additional variables which were used include: Financial development and population (Mahalik and Mallick, 2014); foreign investment and carbon dioxide emissions (Linh and Lin, 2014).

A number of authors concentrated on the different types of energy like electricity, oil, coal, renewable energy and sought to determine co-integration between renewable energy consumption and economic growth (Tugcu et al., 2012; Aslan and Ocal, 2013; and Moubarak and Lin, 2014). Aslan and Ocal (2013) and Moubarak and Lin (2014) confirmed the existence of long run relationship between economic growth and renewable energy consumption. Tugcu et al. (2012) found no evidence of a long run relationship between renewable energy consumption and economic growth.

A number of studies established that electricity consumption and economic growth have a long run relationship (Mozumder and Marathe, 2007; Ahamad et al., 2013; Yuan et al., 2007; Adebola and Shahbaz, 2013; Masuduzzaman, 2013; Tang, 2008; Shahbaz et al., 2011; Narayan and Smith, 2005; Adebola and Shahbaz, 2013; Masuduzzaman, 2013). This studies established that electricity consumption and economic growth move together in a long run.

There are studies that focused attention on the supply side of electricity and concluded that electricity supply and economic growth are co-integrated (Bayraktutan et al. (2011); Sarker 2010; Ghosh (2009); Ellahai (2011); Cerdeira (2012); Samuel and Lionel (2013) and Nnaji et al. (2013). The studies on Africa and South Africa particularly are also characterized by mixed results. Ankilo (2008) investigated the relationship between economic growth and energy consumption in 11 Sub-Saharan African countries. The findings suggested existence of a long run relationship between economic growth and energy consumption in Cote D'Ivoire, Gambia, Ghana, Senegal, Sudan and Zimbabwe. No co-integration was found in Nigeria, Cameroon and Togo.

Wolde-Rufael (2006) undertook a study for 17 African countries and found co-integration between electricity consumption and economic growth for 9 countries only. Akinwale et al. (2013) and Oshota (2015) served to determine the long run relationship between electricity consumption and economic growth in Nigeria. Both their results supported existence of a long run relationship between economic growth and electricity supply. Inglesi-Lotz (2010) and Ziramba (2008) focused on South African electricity consumption and economic growth nexus using Engle-Granger method of co-integration and ARDL bounds testing approach, respectively. The two studies suggested that there is a long run relationship between electricity consumption and economic growth in South Africa. Odhiambo (2009) also evidenced the existence of co-integration between electricity consumption and economic growth in South Africa.

It can therefore be realized that no study was conducted to determine the relationship between electricity supply and economic growth incorporating electricity prices, capital and trade openness in South Africa. Therefore, this current study will endeavor to fill that gap.

3. RESEARCH METHODOLOGY

The paper applies the extended Cobb-Douglas production function where technology is endogenously determined by the level of electricity price and trade openness. The general form of this production therefore is as follows:

$$GDP = AES^{\alpha_1} K^{\alpha_2} L^{\alpha_3} \varepsilon^{\mu} \qquad (3.1)$$

Where, A is technology, GDP is the real gross domestic product, ES is the electricity supply and K, L and e denote real capital, labor and error term respectively. $\alpha_{1,}\ \alpha_2\ \alpha_3$ represent output elasticity with respect to electricity supply, capital and labor, respectively. Trade openness helps stimulate economic growth by allowing flow of resources from one country to another. Increase in global trade helps a country to reap static and dynamic benefits and as a result enhances economic growth. When electricity tariffs are lower, demand for electricity increases and this stimulates economic growth (Adebola, 2011). Therefore, the model can be written as follows;

$$A(t)=\varphi TR(t)^{\alpha}P(t)^{\gamma} \tag{3.2}$$

Then substituting Equation 5.2 into Equation 5.1:

$$GDP(t)=\phi ES(t)^{\gamma_1} TR(t)^{\gamma_2} P(t)^{\gamma_3} K(t)^{\beta} L^{1-\beta} \tag{3.3}$$

Consistent to the studies by Khan et al. (2012) and Shahbaz and Lean (2012) the series in converted into per capita terms by dividing both sides by population. Then a standard log-linear functional specification of the nexus between electricity supply, real GDP, trade openness, capital, labor and electricity price become as follows:

$$GDP_t=\alpha_1+\alpha_{ES}ES_t+\alpha_{TR}TR_t+\alpha_P P_t+\alpha_K K_t+\alpha_{EM}EM_t+\varepsilon_t \tag{3.4}$$

Where; GDP represent the real gross domestic product (using constant prices of 2005), TR is trade openness, ES is the electricity supply measured in gigawatt-hours, EM is the total labor force, K is the capital and P is the price of electricity. The output elasticities with respect to electricity supply, trade openness, electricity price, capital and labor are α_{ES}, α_{TR}, α_P, α_K, α_{EM}, respectively. All the series are expressed in log-linear form as follows:

$$\begin{aligned}LnGDP_t&=\alpha_1+\alpha_{ES}LnES_t+\alpha_{TR}LnTR_t+\alpha_{\mathrm{P}}LnP_t+\alpha_K LnK_t\\&+\alpha_{EM}LnEM_t+\varepsilon t\end{aligned} \tag{3.5}$$

The choice of variables used in the study serves a number of purposes. The first regards the vital role they play to an emerging economy like South Africa. The second is on account of the differences in the results obtained by the earlier studies that used similar variables and methodologies. The third considers the recent developments of the electricity consumption and economic growth examination in South Africa which has not been greatly investigated. Finally, the impact of electricity prices and power outages in South Africa due to lack of the government's response in relation to the policies suggested by earlier studies. For instance, the likes of Gaunt (2008) and Eberhard (2002) proposed that the structure of ESI should be reformed in order to ensure sufficient supply of electricity.

Prior to testing for co-integration, the paper examines the stationarity of each series. There are several unit root tests which have been employed to determine the order of integration. These include a test by Said and Dickey (1984) termed augmented Dickey Fuller (ADF) unit root test and another one by Phillips and Perron (1988) named Phillips-Perron (PP) unit root test.

When the variables are found to be integrated of the same order, the existence of co-integration can be estimated. Co-integration means that one or more linear combinations of time series variables are stationary even though if they are non-stationary when they are not combined (Ziramba, 2008). The ARDL technique was employed.

The application of ARDL bound test in investigating the long run relationship between the variables involves estimating an unrestricted error correction model (UECM) in first difference form (Madhavan et al. 2010). The research utilizes the following UECMs:

$$\begin{aligned}\Delta LnGDP_t &= \alpha_1+\alpha_T T+\alpha_{GDP}LnGDP_{t-1}+\alpha_{ES}LnES_{t-1}\\&+\alpha_{TR}LnTR_{t-1}+\alpha_P LnP_{t-1}+\alpha_K LnK_{t-1}\\&+\alpha_{EM}LnEM_{t-1}+\sum_{i=1}^{p}\alpha_i\Delta LnGDP_{t-i}\\&+\sum_{j=0}^{q}\alpha_j\Delta LnES_{t-j}+\sum_{k=0}^{r}\alpha_k\Delta LnTR_{t-k}+\sum_{l=0}^{s}\alpha_l\Delta LnP_{t-l}\\&+\sum_{m=0}^{t}\alpha_m\Delta LnK_{t-m}+\sum_{n=0}^{u}\alpha_n\Delta LnEM_{t-n}+\varepsilon_{1t}\end{aligned} \tag{3.6}$$

$$\begin{aligned}\Delta LnES_t &= \alpha_1+\alpha_T T+\alpha_{GDP}LnGDP_{t-1}+\alpha_{ES}LnES_{t-1}\\&+\alpha_{TR}LnTR_{t-1}+\alpha_P LnP_{t-1}+\alpha_K LnK_{t-1}\\&+\alpha_{EM}LnEM_{t-1}+\sum_{i=1}^{p}\beta_i\Delta LnES_{t-i}+\sum_{j=0}^{q}\beta_j\Delta LnGDP_{t-j}\\&+\sum_{k=0}^{r}\beta_k\Delta LnTR_{t-k}+\sum_{l=0}^{s}\beta_l\Delta LnP_{t-l}\\&+\sum_{m=0}^{t}\beta_m\Delta LnK_{t-m}+\sum_{n=0}^{u}\beta_n\Delta LnEM_{t-n}+\varepsilon_{2t}\end{aligned} \tag{3.7}$$

$$\begin{aligned}\Delta LnTR_t &= \alpha_1+\alpha_T T+\alpha_{GDP}LnGDP_{t-1}+\alpha_{ES}LnES_{t-1}\\&+\alpha_{TR}LnTR_{t-1}+\alpha_P LnP_{t-1}+\alpha_K LnK_{t-1}\\&+\alpha_{EM}LnEM_{t-1}+\sum_{i=1}^{p}\delta_i\Delta LnTR_{t-i}+\sum_{j=0}^{q}\delta_j\Delta LnGDP_{t-j}\\&+\sum_{k=0}^{r}\delta_k\Delta LnES_{t-k}+\sum_{l=0}^{s}\delta_l\Delta LnP_{t-l}\\&+\sum_{m=0}^{t}\delta_m\Delta LnK_{t-m}+\sum_{n=0}^{u}\delta_n\Delta LnEM_{t-n}+\varepsilon_{3t}\end{aligned} \tag{3.8}$$

$$\begin{aligned}\Delta LnP_t &= \alpha_1+\alpha_T T+\alpha_{GDP}LnGDP_{t-1}+\alpha_{ES}LnES_{t-1}\\&+\alpha_{TR}LnTR_{t-1}+\alpha_P LnP_{t-1}+\alpha_K LnK_{t-1}\\&+\alpha_{EM}LnEM_{t-1}+\sum_{i=1}^{p}\theta_i\Delta LnP_{t-i}+\sum_{j=0}^{q}\theta_j\Delta LnGDP_{t-j}\\&+\sum_{k=0}^{r}\theta_k\Delta LnES_{t-k}+\sum_{l=0}^{s}\theta_l\Delta LnTR_{t-l}\\&+\sum_{m=0}^{t}\theta_m\Delta LnK_{t-m}+\sum_{n=0}^{u}\theta_n\Delta LnEM_{t-n}+\varepsilon_{4t}\end{aligned} \tag{3.9}$$

$$\Delta LnK_t = \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} + \alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} + \alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta LnK_{t-i} + \sum_{j=0}^{q} \varphi_j \Delta LnGDP_{t-j} + \sum_{k=0}^{r} \varphi_k \Delta LnES_{t-k} + \sum_{l=0}^{s} \varphi_l \Delta LnTR_{t-l} + \sum_{m=0}^{t} \varphi_m \Delta LnP_{t-m} + \sum_{n=0}^{u} \varphi_n \Delta LnEM_{t-n} + \varepsilon_{5t} \quad (3.10)$$

$$\Delta LnEM_t = \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} + \alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} + \alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \phi_i \Delta LnEM_{t-i} + \sum_{j=0}^{q} \phi_j \Delta LnGDP_{t-j} + \sum_{k=0}^{r} \phi_k \Delta LnES_{t-k} + \sum_{l=0}^{s} \phi_l \Delta LnTR_{t-l} + \sum_{m=0}^{t} \phi_m \Delta LnP_{t-m} + \sum_{n=0}^{u} \phi_n \Delta LnK_{t-n} + \varepsilon_{6t} \quad (3.11)$$

Where the Δ is defined as the first difference operator, T is the time trend, $LnGDP_t$ is the natural logarithm of gross domestic product, $LnES_t$ is the natural logarithm of electricity supply, $LnTR_t$ is the natural logarithm of trade openness, LnP_t is the natural logarithm of prices, LnK_t is the natural logarithm of capital and $LnEM_t$ is the natural logarithm of employment. It is assumed that the residuals (ε_{1t} ε_{2t} ε_{3t} ε_{4t} ε_{5t} ε_{6t}) are normally distributed and white noise.

To investigate whether there is a long run relationship between the variables, the F-test can be employed using equations from 3.6 to 3.11. This involves testing whether the lagged level variables are significant. To examine the existence of co-integration, the computed F-statistics are compared with the critical values. For each of the equations above, the calculated F-statistics for co-integration are indicated as follows: $F_{GDP}(GDP|ES,TR,P,EM,K)$; $F_{ES}(ES|GDP,TR,P,EM,K)$; $F_{TR}(TR|GDP,ES,P,EM,K)$; $F_P(P|GDP,ES,TR,EM,K)$; $F_{EM}(EM|GDP,ES,TR,P,K)$; $F_K(K|GDP,ES,TR,P,EM)$. The null hypothesis of no co-integration is tested against the alternative hypothesis of co-integration as follows:

H_0: $\alpha_{GDP}=\alpha_{ES}=\alpha_{TR}=\alpha_P=\alpha_{EM}=\alpha_K=0$

V.S.

H_1: $\alpha_{GDP}\neq\alpha_{ES}\neq\alpha_{TR}\neq\alpha_P\neq\alpha_{EM}\neq\alpha_K\neq 0$

The two sets of critical values introduced by Pesaran et al. (2001) include the lower-bounds critical values and the upper-bounds critical values (Shahbaz et al., 2011). The following results are derived from the hypothesis: Firstly, if the computed F-statistics is greater than the upper-bound critical values, the null hypothesis of no co-integration is rejected. Secondly, the null hypothesis of no co-integration cannot be rejected if the computed F-statistics is less than the lower-bound critical values. Lastly, if the computed F-statistics falls between the lower-bound and upper-bound critical values, the results become inconclusive.

Ziramba (2008) purported that the critical values are implemented on larger sample sizes of about 500 and 1000 observations. But Shahbaz et al. (2011) indicated that the critical values from Narayan (2005) are appropriate for small samples of between 30 and 80. Therefore for the purpose of this study, the critical bounds values from Narayan (2005) are used. The stability of long run parameters is examined by applying the Brown et al. (1975) tests termed cumulative sum of recursive residuals (CUSUM) and CUSUM of recursive squares (CUSUMSQ).

The study applies annual data for the period 1985-2014 taken from South African Reserve Bank, IMF international financial statistics and Statistics South Africa data base. The series include: Economic growth, electricity supply, trade openness, electricity prices, capital and employment.

3.1. Research Findings

The results of the ADF and PP tests for stationarity are illustrated in Table 1. The t-statistics for all the variables (*GDP, ESS, TR, P, EM, K, EX* and *IM*) are greater than the critical values at 1%, 5% and 10% levels of significance, respectively, for both ADF and PP tests. This shows that the null hypothesis of unit root hypothesis cannot be rejected, implying that all the variables are non-stationary at the level form. The findings of the first difference suggested that all the variables are stationary at 5% level of significance (Table 1).

3.2. Co-Integration Test

The paper employs the ARDL model to test for the presence of long run relationship among the variables. To select the optimal orders, both the Akaike information criterion and Scharwz's Bayesian information criterion are used. Table 2 presents the results of the

Table 1: Results for unit root tests

Variable	ADF				PP			
	Intercept		Intercept and trend		Intercept		Intercept and trend	
	Level	Δ	Level	Δ	Level	Δ	Level	Δ
GDP	−2.885	−6.046*	−3.904	−5.927*	−2.726	−10.20*	−2.900	−10.14*
ESS	−0.283	−4.120*	−2.352	−3.999**	0.100	−3.601**	−2.352	−3.537***
TR	−0.523	−4.514*	−2.203	−4.432*	−0.480	−4.635*	−2.456	−4.582*
P	0.245	−2.865***	−1.466	−3.059	1.474	−2.865***	−0.797	−3.073
EM	−2.830	−3.555**	−0.280	−4.142**	−2.575	−3.562**	−0.280	−4.042**
K	0.325	−3.462**	−3.096	−3.445***	0.277	−3.380**	−2.477	−3.586**
EX	−2.188	−5.464*	−3.153	−5.639*	−2.072	−6.420*	−2.476	−10.59*
IM	−0.519	−5.302*	−2.810	−5.203*	−0.336	−5.880*	−2.896	−5.770*

Source: Author's own calculations. *,**,***Represent significance at 1%, 5% and 10% levels respectively. The null hypothesis is that the variable has a unit root. ADF: Augmented Dickey Fuller, PP: Phillips-Perron

Table 2: Lag order selection criteria

VAR lag order selection criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	88.9425	NA	1.08e-10	−5.92447	−5.638996	−5.837197
1	257.0393	252.1451	9.18e-15	−15.35995	−13.36164	−14.74905
2	317.0052	64.24918*	2.46e-18*	−17.07180*	−13.36066*	−15.93727*

Source: Author's own calculations. *Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5%). FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion, VAR: Vector autoregression

lag selection test. The AIC and SC established the maximum order of lags as 2 in the ARDL model.

The results for the ARDL bound test, based on Narayan (2005) are illustrated in Table 3. There is also no cointegration found when trade openness, electricity supply and capital are used as dependent variables because their F-statistics 1.79, 1.68 and 2.28, respectively, are less than lower critical bound values at 5% levels of significance (Table 3). When economic growth, electricity prices and employment are used as dependent variables, co-integration is established. This is because the F-statistics 4.10 is greater than the upper critical bound value of 3.625 at 5% level of significance when economic growth is the dependent variable.

When electricity price and employment are dependent variables, the F-statistics of electricity price (4.88) and employment (8.05) are greater than the upper critical bound values at both 1 and 5% levels of significance. The overall results exhibit three co-integrated equations. This indicates that there is a long run relationship between economic growth, electricity supply, trade openness, electricity price, employment and capital in South Africa.

Having determined the long run relationship between the variables, the next step is to estimate the long run and short run coefficients of the impact of electricity supply, trade openness, electricity prices, capital and employment on economic growth. The results for long run and short run elasticities are reported in Tables 3 and 4, respectively.

The results exhibit that electricity supply has a long run positive effect on economic growth. All else the same, a 1% increase in electricity supply is expected to increase economic growth by 3.94%. The results are in line with the findings of Ellahai (2011) and Yoo and Nnaji et al. (2013) who established that increasing electricity supply stimulates economic growth in Pakistan and Nigeria, respectively.

The results further portray a negative long relationship between economic growth and electricity prices. The relationship is such that a 0.036% decrease in economic growth is associated with an increase of a 1% of electricity prices, ceteris paribus. This is in line with economic growth theory and is consistent with the findings of Odhiambo (2010).

Table 4 illustrates that the effect of employment on economic growth is positive and significant at 1% level of significance. It is such that a 1% increase in employment is associated with an increase in economic growth on an average of 9.01%, when all other variables

Table 3: F-statistics for co-integration

Critical value bound of the F-statistic						
K	90% level		95% level		99% level	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
3	2.022	3.112	2.459	3.625	3.372	4.797
4	1.919	3.016	2.282	3.340	3.061	4.486

Source: Author's own calculations. Calculated F-statistics. F_{RGDP} (R_{GDP}/*ES, TR, P, EM, K*)=4.10, F_{ES} (*ES/RGDP, TR, P, EM, K*)=1.68, F_{TR} (*TR/RGDP, ES, P, EM, K*)=1.79, F_{P} (*P/* R_{GDP} *ES, TR, EM, K*)=4.88, F_{EM} (*EM/*RGDP*, ES, TR, P, K*)=8.05, F_{K} (*K/* R_{GDP}*, ES, TR, P, EM*)=2.28. The critical bound values were taken from Narayam and Smyth (2005. p. 470). RGDP: Real gross domestic product

Table 4: Long run analysis

Dependent variable=Ln RGDP			
Long run results			
Variable	Coefficient	Standard error	t-statistics
Constant	35.2693	60.8849	0.5793
Ln ES	3.9420	4.4665	−0.8826
Ln TR	3.649	2.2305	−1.6355
Ln P	−0.0359	0.2179	−0.1645
Ln EM	9.0107	2.7278	3.3033
Ln K	1.5472	1.0331	1.4977
R^2	0.45		
F-statistics	4.05*		
D.W test	1.64		

Source: Author's own calculations. *Represent 1% significance level. RGDP: Real gross domestic product

are held constant. These results support economic growth theory and confirm the outcomes of Odhiambo (2009) and Wolde-Rufael (2009) for South Africa and Shahbaz et al. (2011) for Portugal.

The findings further show that capital formation is positively related to economic growth in the long run. All else the same, a 1% increase in capital formation is anticipated to raise economic growth on an average of 1.55%. These results are also in line with economic growth theory and consistent with the outcomes of Adebola (2011) and Apergis and Payne (2011).

Finally, the impact of trade openness on economic growth is positive and significant at 10% level of significance. Ceteris paribus, a 1% increase in trade openness is expected to increase economic growth by 3.65%. This confirms the results found by Nasreen and Anwar (2014) and Khan et al. (2012).

Table 5 discusses the short run results. The impact of electricity supply on economic growth is found to be positive but not significant at 5% level of significance. The short run results also show that electricity prices have a negative impact on economic growth contrary to economic growth theory. The results on employment and capital formation support a positive short run effect on economic growth even though not significant at 5% level of significance.

The estimate of the ECM_{t-1} is −0.82. For the results to support a long run relationship, the ECM should be negative and significance (refer to Chapter 3). The results in Table 5 show that ECM is negative and significant at 5% level of significance. This means that it supports the long run relationship among the variables. The results indicate that the short run deviations from long run equilibrium are corrected by 82.06% towards long run equilibrium each year (Table 5).

The diagnostic tests were taken as shown in Table 6. It was found that the error terms of the short run models have no serial correlation, free of heteroscedasticity and are normally distributed. The short run models were found not to be spurious because the Durban-Watson statistics was found to be greater than the R^2.

The problem with time series regressions is that the estimated parameters alternate over time (Narayam and Smyth, 2005). The instability of the parameters leads to misspecification, which in turn leads to biased results. The stability of long run parameters was examined by applying cumulative sum of recursive residuals (CUSUM) and CUSUM of recursive squares (CUSUMSQ).

Figures 2 and 3 demonstrate cumulative sum of recursive residuals. The null hypothesis cannot be rejected at 5% level of significance if the plot of test falls within the critical limits. It can be concluded that short run and long estimates are efficient and reliable because Figures 2 and 3 illustrate that the graph of the test lie between the upper and lower critical limits.

4. CONCLUSION AND POLICY RECOMMENDATION

This paper examined the long run and short run relationship between economic growth, electricity supply, trade openness, electricity prices, employment and capital in South Africa using annual data over the period 1985-2014. To the best of the researcher’s knowledge, this is the first study to determine the relationship between economic growth and electricity supply in South Africa. The ARDL model was applied to assess cointegration among the variables.

The findings revealed that economic growth, electricity supply, trade openness, electricity prices, employment and capital move together in the long run. There were three co-integration equations. The results suggest that electricity prices have a negative impact on economic growth. The results further evidenced that electricity supply, trade openness, employment and capital have a positive impact on economic growth in the long run.

The results point out that a 1% increase in electricity supply leads to an increase in economic growth by 3.94% on average. The findings of this paper validated that electricity supply has a positive impact on economic growth in South Africa. It is

Table 5: Short run analysis

Short run results			
Variable	**Coefficient**	**Standard error**	**t-statistics**
Constant	−0.1506	0.2222	−0.6778
Ln ESS	0.2139	4.7436	−0.0451
Ln TR	2.6140	2.3498	−1.1124
Ln P	−0.1899	0.7332	0.2590
Ln EM	10.2918	5.7410	1.7927
Ln K	0.6063	1.4389	0.4214
ECM_{t-1}	−0.8206*	0.2181	−3.7626
R^2	0.47		
F-statistics	3.25**		
D.W test	1.897		

Source: Author’s own calculations. *.**Represent 1%, 5% and 10% significance levels respectively

Table 6: Short run diagnostic test

Short run diagnostic test						
Test	**F-statistics**	**P value**	**F-statistics**	**P value**	**F-statistics**	**P value**
Normality	0.5639	0.7543	2.8665	0.2385	137.3199	0.0000
Heteroscedasticity	10.8699	0.7212	3.3737	0.0249	3.0703	0.0332
Serial correlation	2.0177	0.3654	0.7959	0.5829	0.4705	0.0962

Source: Author’s own calculations

Figure 2: Plot of cumulative sum of recursive residuals

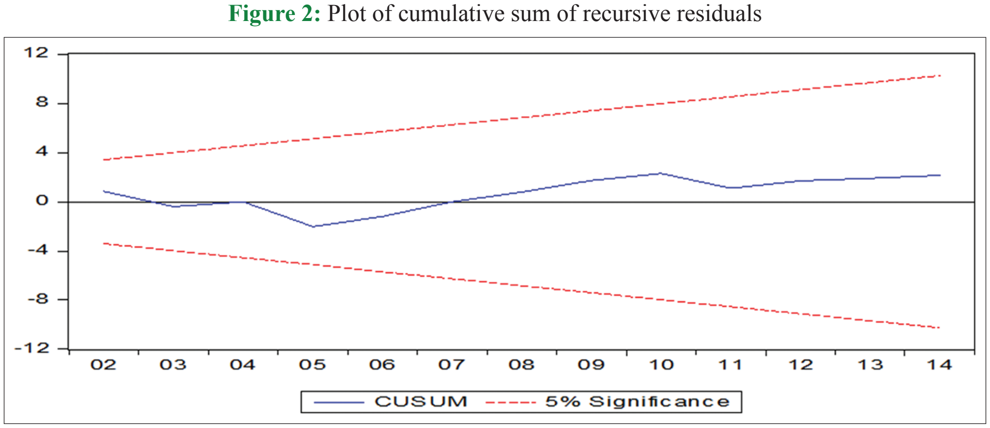
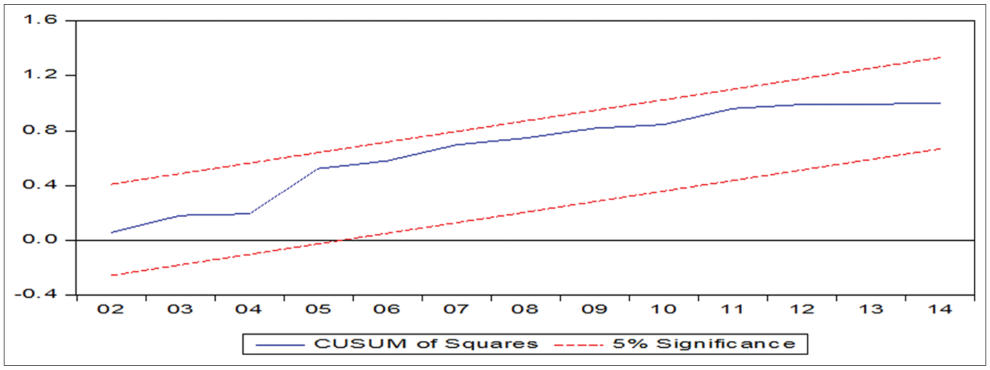


Figure 3: Plot of cumulative sum of squares of recursive residuals



therefore, necessary to ensure secure, reliable, efficient, clean and sustainable electricity in the country. The government and policy makers should also advocate for restructuring of the electricity supply industry. This will lead to more supply of electricity as more players will be allowed entry into this industry. Therefore, the policymakers should select electricity policies which will support economic growth in South Africa.

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