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Article

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The Impact of Electricity Price on Economic Growth in South Africa

Hlalefang Khobai[1]*, Gift Mugano[2], Pierre Le Roux[3]

[1]Department of Economics, Nelson Mandela Metropolitan University, South Africa, [2]Department of Economics, Nelson Mandela Metropolitan University, South Africa, [3]Department of Economics, Nelson Mandela Metropolitan University, South Africa.
*Email: hlalefangk@gmail.com

ABSTRACT

This study explores the relationship between electricity prices and economic growth in South Africa within a multivariate framework over the period 1985-2014. The autoregressive distributed lag (ARDL) bounds test is implemented to determine long run relationship among the variables. The findings of the ARDL model suggest that there is a long run relationship between electricity supply, economic growth, electricity prices, trade openness, employment and capital. Specifically, the empirical findings reveal that electricity prices negatively affect economic growth while electricity supply, trade openness, capital and employment have a positive impact on economic growth. These findings bring a fresh perspective for creating electricity policies that will enhance economic growth in South Africa.

Keywords: Economic Growth, Electricity Prices, South Africa
JEL Classifications: O13, O4, Q43

1. INTRODUCTION

South Africa has seen the fasted growth in electricity demand post the apartheid era. This was on account of the fast growth in economic growth and the country's plan of ensuring electricity access to two-thirds of the population. Unfortunately electricity supply could not catch up with the high increases in demand. Eskom (the electricity utility) had to come up with projects to increase electricity supply. The electricity expansion programme was developed.

Eskom's capacity expansion programme began in 2005. It is the largest in the history of Eskom's projects and it was expected to raise its transmission lines by 4700 km while the generation capacity would increase by 17120 MW (Eskom, 2012b). The main objective of the capacity expansion programme was to meet the ever increasing demand and also diversify Eskom's energy sources (Eskom, 2012b). Eskom has budgeted R385 billion for its capacity expansion programme up to 2013 and it was anticipated to increase to a trillion or more by 2026, with a double capacity of 80000 MW (Eskom, 2012a). For the 6 years of its operation, the capacity expansion programme had already cost R140 billion and is estimated to cost R340 billion when it is completed in 2018. The amount of new generation capacity which has already been installed currently is 5500 MW, in addition to the existing capacity of 39794 MW (Botes, 2012).

The construction of the power stations is increasingly costing South Africa in terms of the budget and delays in building. For example, the prices of household consumers went up by 137% in 2011, following the 2010 approval of the Medupi Project (Sourcewatch, 2012). Over and above, Eskom proposed another increase of 25% increase in order to finance the Kusile power station.

The persistent delays and increases in the budget for the construction of the power stations date back to 2006. Medupi power station's first unit was planned to be produced by January 2010 with an initial cost estimated to be R17 billion, which is equivalent to R9.4 m/MW for the expansion of 1800 MW (Urbach, 2012). The trends of the size, budget and the delays in the construction of Medupi power station are as follows (Urbach, 2012):

i. In March 2006, the expansion of 1800 MW budget price increased from R17 billion to R20 billion which is between R9.4 m/MW and R11.1 m/MW on average.
ii. In January 2007, the Medupi power station size was changed to 4500 MW, costing over R52 billion and the first unit was reported to be commissioned in mid-2011.
iii. In February 2007, the price was confirmed to be R56 billion (which is equivalent to R12.44 m/MW on average) and delayed by 1½ years.
iv. Late February 2007, the budget was announced to have increased to R70 billion, but was confirmed to cost R66 billion (an equivalent of R14.67 m/MW on average) in May.
v. In October 2007, the station was announced to be expanded to 4700 and then to 4800 in the same month, with the cost increasing to R78.66 billion (equivalent of R16.37 m/MW on average). The first unit was then to be commissioned to the third quarter of 2011, a delay of 2 years.
vi. As of March 2011, the budget increased to R120 billion from R78.6 billion in October 2007. The date of commissioning the power station was postponed to June 2012, a delay of 2½ years, with a budget price equivalent to R26.15 m/MW.
vii. In July 2012, the size was 4764 MW, costing R91.2 billion when excluding interest during construction (IDC). The commission date has been postponed to December 2013. By December 2013, it is projected that the power station will be costing R130 billion including IDC. This is now gone to 3 years.

From the above changes in the size, budget and time scheduled for completion of the Medupi power station, it can be seen that billions of rands are being lost on the construction of the power station alone. It can also be seen that the times for commissioning have been postponed, which means there is still lack of enough capacity generated for consumers.

To finance the energy transition, the cost of building new generation station and bringing in new energy technologies into the industry are passed on to the consumers, predominantly through energy prices (i.e. electricity prices). A large number of levies as well as the electricity tax are currently raising the price of electricity and thereby the electricity costs of the industries. It is therefore important to investigate the relationship between electricity prices and economic growth in South Africa to come up with the correct and appropriate price regime which will support economic growth. This study also serves to determine the effect of electricity supply, trade openness, capital and employment on economic growth.

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

2. LITERATURE REVIEW

The impact of electricity prices has not been given much attention by growth economists. It is important to consider the degree of the influence that the changes of electricity price has on economic development and on electricity consumption. This facilitates the accurate selection of electricity price policy. Most authors who studied the impact of electricity prices on economic growth investigated the relationship between electricity consumption and economic growth and included electricity prices as an intermittent variable (Belke et al., 2010; Hondroyiannis et al., 2012; Madhavan et al., 2010 and Odhiambo, 2010; Bhattacharya et al., 2016).

Research by Hondroyiannis et al. (2012) examined the relationship between energy consumption and economic growth using a trivariate framework where price development was used as the third variable. The study considered the data for Greece from 1960 to 1996, using the vector error correction model (VECM) estimation. Their empirical results supported the notion of a long term relationship between economic growth, energy consumption and price developments, and further suggested that aggregate energy consumption, Granger-causes economic growth. But disaggregated energy consumption suggested that industrial energy consumption strongly Granger-causes economic growth while residential energy consumption weakly Granger-causes economic growth.

Belke et al. (2010) incorporated energy prices in their study as the intermittent variable to explore the causal relationship between energy consumption and economic growth in 25 OECD countries. The data used in the study covered the period between 1981 and 2007. The results showed that different developments in different countries have a significant impact on the co-integration between real GDP and energy consumption. The Granger-causality results indicated a feedback hypothesis between energy consumption and economic growth. The results further suggested that an increase in energy prices leads to a fall in energy consumption and that economic growth affects energy prices.

Masih and Masih (1998) researched the co-integration and Granger-causality between real income, energy consumption and price levels, using the most recent Johansen's multiple co-integration tests. The study considered data for two Asian less developed countries, namely Sri Lanka and Thailand. The variables were found to be co-integrated. The results from the VECM indicated that there is a neutral hypothesis between income and prices. Energy consumption was found to be causing income and prices.

Madhavan et al. (2010) undertook a trivariate study to determine the relationship between electricity consumption and economic growth in Malaysia. The electricity price was used as an intermittent variable to form a trivariate framework. Time series data was employed in this study covering the period from 1971 to 2003. The researchers used the auto regressive distributed lag (ARDL) model and their results revealed the existence of a long term relationship between economic growth, electricity consumption and price. The Granger-causality results revealed a one-way causality flowing from electricity consumption to economic growth.

Another study that included price as an intermittent variable was done by Asafu-Adjaye (2000). In this study, however, instead of using the electricity consumption-economic growth nexus, Asafu-Adjaye's (2000) study considered energy consumption-economic growth relationship. This study was based on data for India, Indonesia, the Philippines and Thailand and used co-integration tests and the error correction modelling technique to analyse co-integration and causality between these variables, respectively. The Indian and Indonesian results identified short-run Granger-causality flowing from energy consumption to income while the results for Thailand and the Philippines detected bidirectional causality between these results. The empirical results further showed a unidirectional causality from prices to energy consumption in the Philippines and Granger-causality from energy and prices to income.

Odhiambo (2010) conducted a research to investigate the relationship between economic growth and energy consumption and included prices as the third variable. The study used data for three Sub-Saharan countries: Congo (DRC), Kenya and South Africa. The ARDL bounds tests revealed different results for various countries. A one-way Granger-causality flowing energy consumption to economic growth was established for Kenya and South Africa whereas the opposite direction of causality was found for the Congo (DRC). The results further showed a unidirectional causality flowing from prices to economic growth in Kenya while in the short-run, the direction of causality was found to be flowing from energy consumption to prices. The results for the Democratic Republic of Congo (DRC) described a one-way causality flowing from energy consumption to prices in the long term while in the short-term; the causality was found to flow from prices to economic growth.

Bekhet and Othman (2011) examined the interrelationship between gross domestic product, electricity consumption, consumer price index and foreign direct investments. The data used in this study covered the period between 1971 and 2009. The results from the VECM found a long term relationship between these variables. The results indicated a unidirectional causality flowing from electricity consumption to foreign direct investment, economic growth and inflation. This implies that Malaysia is an electricity independent country and to achieve economic stability and growth, it is crucial to maintain a sustainable electricity supply. The results further showed a one way Granger-causality flowing from electricity consumption to inflation. This means that increasing electricity consumption has had an impact on inflation.

The most recent study to investigate the relationship between economic growth, electricity consumption, employment and inflation was done by Abbas et al. (2014). The study utilised data covering the period from 1990 to 2012 for the following five developing countries: China, India, Malaysia, Pakistan and South Africa. The random generalised least squares (GLS) model and Hausman's specification tests were used in this study. The results showed a significant impact of employment and electricity consumption on economic growth but an insignificant impact of inflation on economic growth. This implies that policy makers should focus on improving electricity supply to meet demand and this will lead to the enhancement in the employment rate which should in turn boost economic growth in the developing countries. Therefore, it is important to ensure that there is enough supply of electricity to meet the demand.

3. METHODOLOGY

The theoretical literature has shown that economic growth is related to electricity prices and electricity supply. Therefore, theoretical economic growth function can be presented as follows:

$$GDP_t = f(ES_t, P_t) \tag{1}$$

Where, GDP_t is the real gross domestic product, ES_t is electricity supply, P_t is the electricity prices. In line with the objectives of this study, trade openness, capital and employment are included in the economic growth function as intermittent variables. Therefore, the new economic growth model is written as follows:

$$GDP_t = \alpha_1 + \alpha_{ES} P_t + \alpha_{TR} TR_t + \alpha_P ES_t + \alpha_K K_t + \alpha_{EM} EM_t + \varepsilon_t \tag{2}$$

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 labour 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 labour are α_{ES}, α_{TR}, α_P, α_K, α_{EM}, respectively. All the series are expressed in log-linear form as follows:

$$\begin{aligned} LnGDP_t = {} & \alpha_1 + \alpha_{ES} LnP_t + \alpha_{TR} LnTR_t + \alpha_P LnES_t + \alpha_K LnK_t \\ & + \alpha_{EM} LnEM_t + \varepsilon_t \end{aligned} \tag{3}$$

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

Testing for stationarity of the series has become one of the popular tests. This is on account that undertaking unit root test to determine stationarity of variables helps prevent spurious results. The augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests will be employed to test for stationary.

If the results from ADF and PP unit root test indicate that the variables are integrated of the same order, then co-integration test can be conducted. 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 study applied ARDL bounds test.

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 applies the following UECMs:

$$\begin{aligned}\Delta LnGDP_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} \\ &+\alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} \\ &+\alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta LnGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LnES_{t-j} \\ &+\sum_{k=0}^{r} \alpha_k \Delta LnTR_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta LnP_{t-l} \\ &+\sum_{m=0}^{t} \alpha_m \Delta LnK_{t-m} + \sum_{n=0}^{u} \alpha_n \Delta LnEM_{t-n} + \varepsilon_{1t}\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta LnES_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} \\ &+\alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} \\ &+\alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \beta_i \Delta LnES_{t-i} + \sum_{j=0}^{q} \beta_j \Delta LnGDP_{t-j} \\ &+\sum_{k=0}^{r} \beta_k \Delta LnTR_{t-k} + \sum_{l=0}^{s} \beta_l \Delta LnP_{t-l} \\ &+\sum_{m=0}^{t} \beta_m \Delta LnK_{t-m} + \sum_{n=0}^{u} \beta_n \Delta LnEM_{t-n} + \varepsilon_{2t}\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta LnTR_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} \\ &+\alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} \\ &+\alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \delta_i \Delta LnTR_{t-i} + \sum_{j=0}^{q} \delta_j \Delta LnGDP_{t-j} \\ &+\sum_{k=0}^{r} \delta_k \Delta LnES_{t-k} + \sum_{l=0}^{s} \delta_l \Delta LnP_{t-l} \\ &+\sum_{m=0}^{t} \delta_m \Delta LnK_{t-m} + \sum_{n=0}^{u} \delta_n \Delta LnEM_{t-n} + \varepsilon_{3t}\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta LnP_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} \\ &+\alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} \\ &+\alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \theta_i \Delta LnP_{t-i} + \sum_{j=0}^{q} \theta_j \Delta LnGDP_{t-j} \\ &+\sum_{k=0}^{r} \theta_k \Delta LnES_{t-k} + \sum_{l=0}^{s} \theta_l \Delta LnTR_{t-l} \\ &+\sum_{m=0}^{t} \theta_m \Delta LnK_{t-m} + \sum_{n=0}^{u} \theta_n \Delta LnEM_{t-n} + \varepsilon_{4t}\end{aligned} \tag{7}$$

$$\begin{aligned}\Delta LnK_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} \\ &+\alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} \\ &+\alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta LnK_{t-i} + \sum_{j=0}^{q} \varphi_j \Delta LnGDP_{t-j} \\ &+\sum_{k=0}^{r} \varphi_k \Delta LnES_{t-k} + \sum_{l=0}^{s} \varphi_l \Delta LnTR_{t-l} \\ &+\sum_{m=0}^{t} \varphi_m \Delta LnP_{t-m} + \sum_{n=0}^{u} \varphi_n \Delta LnEM_{t-n} + \varepsilon_{5t}\end{aligned} \tag{8}$$

$$\begin{aligned}\Delta LnEM_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} LnGDP_{t-1} + \alpha_{ES} LnES_{t-1} \\ &+\alpha_{TR} LnTR_{t-1} + \alpha_P LnP_{t-1} + \alpha_K LnK_{t-1} \\ &+\alpha_{EM} LnEM_{t-1} + \sum_{i=1}^{p} \phi_i \Delta LnEM_{t-i} + \sum_{j=0}^{q} \phi_j \Delta LnGDP_{t-j} \\ &+\sum_{k=0}^{r} \phi_k \Delta LnES_{t-k} + \sum_{l=0}^{s} \phi_l \Delta LnTR_{t-l} \\ &+\sum_{m=0}^{t} \phi_m \Delta LnP_{t-m} + \sum_{n=0}^{u} \phi_n \Delta LnK_{t-n} + \varepsilon_{6t}\end{aligned} \tag{9}$$

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_3, ε_{4t}, ε_{5t}, ε_{6t}) are normally distributed and white noise.

To determine whether there is a long run relationship between the variables, the F-test can be applied using equations from 4 to 9. This means testing whether the lagged level variables are significant. To investigate 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: $\alpha_{GDP} = \alpha_{ES} = \alpha_{TR} = \alpha_P = \alpha_{EM} = \alpha_K = 0$

versus

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

Pesaran et al. (2001) introduced two sets of asymptotic critical values that are lower-bounds critical values and upper-bounds critical values. All the explanatory variables are assumed to be I(0) for the lower bound of the critical values whiles the upper bound of the critical values assumes that all the explanatory variables are I(1). But for the purpose of this study, the critical values tabulated by Pesaran et al. (2001) are not applicable because the sample size is relatively small (N = 30). Dues to this problem of small sample sizes, Narayan (2005) provided a new set of critical values for sample sizes between 30 and 80. With regard to this, the study uses the critical bound values by Narayan (2005).

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. The stability of long run parameters is determined by estimating the Brown et al. (1975) tests termed cumulative sum of recursive residuals (CUSUM) and CUSUM of recursive squares (CUSUMSQ).

4. RESEARCH FINDINGS

Table 1 presents the results of the ADF and PP tests for stationarity. 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 implies that all the variables are non-stationary at the level form. The results also reveal that all variables are stationary at first differences. Therefore, these unit root tests suggest that economic growth, electricity supply, trade openness, electricity prices, capital and employment are integrated of order one, I(1).

4.1. Co-integration Test

The ARDL bounds test was used to estimate the existence of a long run relationship between economic growth, electricity supply, trade openness, electricity prices, employment and capital. The Akaike information criterion and Scharwz's Bayesian information criterion are used to select the optimal orders. The results of lag selection test are illustrated in Table 2. The findings from AIC and SC supports the maximum lag order of 2 in the ARDL model as illustrated in Table 2.

Table 3 presents the outcomes of the ARDL bounds test based on Narayan (2005). The computed F-statistics of trade openness, electricity supply and capital 1.79, 1.68, 2.28, respectively, are less than the lower-bound critical values. This means that the null hypothesis of no co-integration cannot be rejected at 5% level of significance. Therefore, when electricity supply, trade openness and capital are taken as dependent variables, there is no co-integration among the variables. The computed F-statistics of economic growth, electricity prices and employment 4.10, 4.88 and 8.05, respectively, are greater than the upper critical bound values. This implies that the null hypothesis of no co-integration is rejected at 5% level of significance. Hence, co-integration between the variables is revealed when economic growth, electricity prices and employment are used as dependent variables.

The Johansen co-integration technique which aims to determine the robustness of the ARDL bounds test was also undertaken. The results of the maximum Eigen value and the Trace test are reported in Table 4. Commencing with the Trace test, the study determines the number of co-integrated equations. The null hypothesis, which

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*

*.** and *** represent significance at 1%, 5% and 10% levels respectively. The null hypothesis is that the variable has a unit root. Source: Author's own calculations

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*

*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. Source: Author's own calculations states that none of the equations are co-integrated, was tested against the alternative hypothesis that there are co-integrated equations. Table 4 indicates that the null hypothesis (R = 0) was rejected at the 5% level of significance. This implies that there was co-integration.

This section proceeds with the null hypothesis of at most 1 (R ≤ 1) against the alternative hypothesis of at least one. The null hypothesis of at most one was strongly rejected which implies that there was at least one co-integrated equation. The results the null hypothesis of (R ≤ 2) at the 5% level of significance. The findings proved that these models support the finding that there are at least two co-integrated equations. The opposite results were found for R ≤ 3. The null hypothesis was rejected and this implies the number of co-integrated equations cannot be more than three.

The results from the maximum Eigen values also demonstrated similar results to the trace statistics results (Table 5). This is because the null hypothesis of (R = 0, R ≤ 1 and R ≤ 2) were rejected at the 5% level of significance. This means that using the maximum Eigen values, there was evidence of at least more than two co-integrated equations. The study further showed similar findings to the Trace statistics results in that the null hypothesis of (R ≤ 3) cannot be rejected at the 5% level of significance, implying that the number of co-integrated equations is not more than three.

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

Calculated F-statistics. F_{RGDP} (RGDP/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/RGDP, ES, TR, EM, K)=4.88, F_{EM} (EM/RGDP, ES, TR, P, K)=8.05, F_{K} (K/RGDP, ES, TR, P, EM)=2.28. The critical bound values were taken from Narayan and Smyth (2005: 470). Source: Author's own calculations

Table 4: Trace test

F_{RGDP} (RGDP/ES, TR, P, EM, K)			
Hypothesis	Trace statistics	0.05 critical values	P value
None	155.9768	95.7537	0.000
At most 1	92.3250	69.8189	0.003
At most 2	51.9452	47.8561	0.020
At most 3	26.4751	29.7971	0.1151
At most 4	9.4778	15.4947	0.323
At most 5	1.1844	3.841	0.277

Source: Author's own calculations

Table 5: Maximum eigen value

F_{RGDP} (RGDP/ES, TR, P, EM, K)			
Hypothesis	Max-Eigen statistic	0.05 critical values	P value
None	63.6518	40.078	0.000
At most 1	40.3798	33.877	0.007
At most 2	25.4701	27.584	0.041
At most 3	16.997	21.132	0.172
At most 4	8.2935	14.265	0.350
At most 5	1.1844	3.841	0.277

Source: Author's own calculations

In summarising the co-integration results, it can be seen from the maximum Eigen values and the trace statistics that there were three co-integrated equations. This supported the ARDL bounds tests which indicated that co-integration existed when trade openness, employment and capital formation were used as the dependent variables. Therefore, it can be concluded that there is a long term relationship between economic growth, electricity supply, trade openness, employment and capital formation in South Africa.

When the long run relationship between economic growth, electricity supply, trade openness, electricity prices, capital and employment has been determined, the ARDL model can be applied to estimate the long run and short run elasticities. Tables 6 and 7 illustrate the results of the long run and short run elasticities, respectively.

The results portray that electricity supply has a long run positive effect on economic growth. The coefficient on electricity supply is positive and significant with a 1% increase in electricity supply generating between 3.94% increase in economic growth, ceteris paribus. The results are consistent with Yoo and Kim (2006), Ellahi (2011) and Nnaji et al. (2013). The results of this study are however, more convincing because they include trade openness, electricity prices, employment and capital.

The results further exhibit a negative long run relationship between economic growth and electricity prices. The coefficient on electricity prices is negative and significant with a 1% increase in electricity prices being associated with a 0.036% decreases in

Table 6: Long run analysis

Dependent variable=Ln RGDP			
Long run results			
Variable	Coefficient	Standard error	T-statistics
Constant	35.2693	60.8849	0.5793
LnES	3.9420	4.4665	−0.8826
LnTR	3.649	2.2305	−1.6355
LnP	−0.0359	0.2179	−0.1645
LnEM	9.0107	2.7278	3.3033
LnK	1.5472	1.0331	1.4977
R^2	0.45		
F-statistics	4.05*		
D.W test	1.64		

*represent 1%, significance level. Source: Author's own calculations

Table 7: Short run analysis

Short run results			
Variable	Coefficient	Standard error	T-statistics
Constant	−0.1506	0.2222	−0.6778
LnESS	0.2139	4.7436	−0.0451
LnTR	2.6140	2.3498	−1.1124
LnP	−0.1899	0.7332	0.2590
LnEM	10.2918	5.7410	1.7927
LnK	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		

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

economic growth, all else the same. These findings are in line the Odhiambo's (2010) results.

The effect of employment on economic growth is positive and significant at 1% level of significance. When all other variables are held constant, a 1% increase in employment generates an increase in economic growth on an average of 9.01%. These results are consistent with economic growth theory and supports the outcomes of Odhiambo (2009) and Wolde-Rufael (2009) for South Africa and Shahbaz et al. (2011) for Portugal.

The results further demonstrate that capital formation is positively related to economic growth in the long run. A 1% increase in capital formation is anticipated to raise economic growth on an average of 1.55%, all other variables held constant. These results are also consistent with economic growth theory and confirms the outcomes of Apergis and Payne (2011) and Adebola (2011).

Finally, the impact of trade openness on economic growth is positive and significant at 10% level of significance. All else the same, a 1% increase in trade openness is associated with an increase economic growth by 3.65%. These findings are similar to the results found by Nasreen and Anwar (2014) and Khan et al. (2012).

Table 7 shows the short run relationship between electricity prices and economic growth. It is realised that the lagged error correction term is negative and significant at 5% level of significance. This indicates the stability of the model and gradual adjustment of the economic growth towards its equilibrium with electricity prices, electricity supply, trade openness, employment and capital variables. The error correction term value is −0.82. This means that the short run deviations from long run equilibrium are corrected by 82.06% towards long run equilibrium each year.

The empirical results further uncover a negative and significant effect of electricity prices on economic growth in the short run. The electricity supply also has a positive effect on economic growth even though not significant at 5% level of significance. Similar results of a positive but no significant short run impact on economic growth were also found on employment and capital.

Table 8 illustrates the diagnostic tests which analyse serial correlation, functional form and heteroscedasticity problems. No econometric dilemma was established, which means 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 (Narayan 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 investigated by applying cumulative sum of recursive residuals (CUSUM) and CUSUM of recursive squares (CUSUMSQ).

Figures 1 and 2 illustrate the cumulative sum (CUSUM) and CUSUM of squares tests, which suggest no structural instability in the residuals of equation characterising the dynamics of economic growth with respect to electricity supply, trade openness, electricity prices, employment and capital. The Figures 1 and 2 show that the plot of the CUSUM and CUSUM of squares statistics fluctuate within the 5% critical bounds. Therefore, the estimated coefficients are stable over the sample period from 1985 to 2014.

5. CONCLUSION AND POLICY RECOMMENDATION

This paper investigated the relationship between electricity prices and economic growth in South Africa by employing the ARDL bounds testing procedure to identify the long run equilibrium

Table 8: 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 1: Plot of cumulative sum of recursive residuals

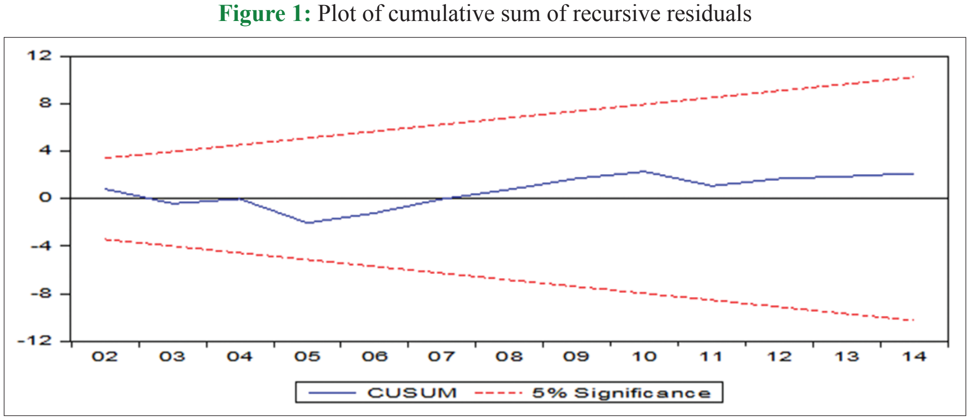
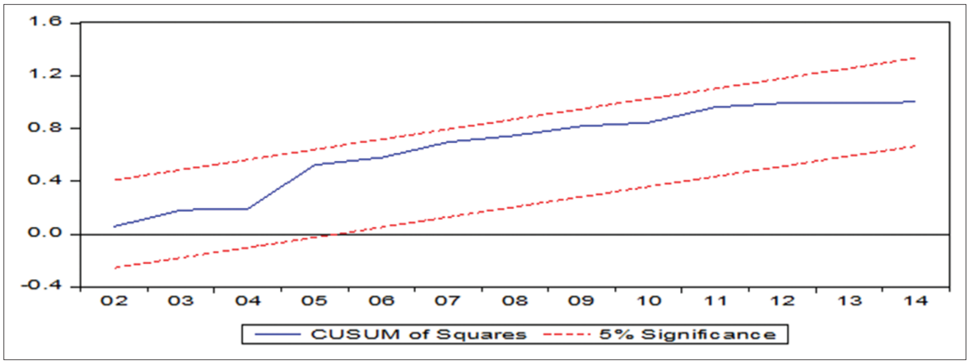


Figure 2: Plot of cumulative sum of squares of recursive residuals



relationship. This paper added electricity supply, trade openness, capital and employment as intermittent variables to form a multivariate framework covering the period between 1985 and 2014.

The results from the ARDL bounds test reveal that there is existence of a long run relationship between economic growth, electricity prices, electricity supply, trade openness, employment and capital when electricity prices, economic growth and employment are used as the dependent variables. The coefficients on electricity supply, trade openness, employment and capital are positive and significant, meaning that an increase in these variables boosts economic growth. On contrary, the coefficient on electricity price is negative and significant. This implies that all else held constant, a 1% increase in electricity prices causes economic growth to drop by 0.036%.

The empirical results emanating from this study give policy makers a better understanding of the importance of an efficient supply of electricity on economic growth. This is on account that economic growth supports expansion of the major sectors of the economy such as industrial and commercial sectors where electricity has been used as basic energy input. Furthermore, research into this topic raises awareness on the potential loss in economic growth caused by increases in electricity prices. Therefore, it is crucial that in finding the balance between high electricity demand and low supply, policy makers should allow more players into the electricity supply industry to help boost supply instead of resorting to increasing the electricity prices.

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