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Kontakt/Contact

ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics
Düsternbrooker Weg 120
24105 Kiel (Germany)
E-Mail: [rights\[at\]zbw.eu](mailto:rights[at]zbw.eu)
<https://www.zbw.eu/econis-archiv/>

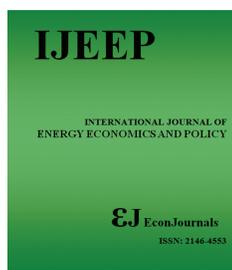
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Exploring the Nexus of Electricity Supply and Economic Growth in South Africa

Hlalefang Khobai^{1*}, Gift Mugano², Pierre Le Roux³

¹Department of Economics, Nelson Mandela Metropolitan University, South Africa, ²Department of Economics, Nelson Mandela Metropolitan University, South Africa, ³Department of Economics, Nelson Mandela Metropolitan University, South Africa.

*Email: hlalefangk@gmail.com

ABSTRACT

This paper investigates the causal relationship between electricity supply and economic growth in South Africa using annual data covering the period between 1985 and 2014. This paper used a multivariate framework which included trade openness, electricity price, capital and employment as intermittent variables. The autoregressive distributed lag bound testing was employed to establish the long run relationship between these variables. The vector error correction model (VECM) was estimated to carry out the test of causality. The results support the existence of co-integration among the variables. The VECM established a bidirectional causality flowing between electricity supply and economic growth. This shows that the policy makers should prioritise building capacity additions and infrastructure development of the South African electricity supply industry, as this will stimulate economic growth and increase electricity in the country. The findings further show that electricity prices, trade openness, employment and capital Granger-cause economic growth and electricity supply. This result means that increased economic growth and electricity supply is dependent on the degree of trade openness, employment levels in the country and the amount of investment.

Keywords: Electricity Supply, Economic Growth, South Africa, Causality

JEL Classifications: Q32, Q43

1. INTRODUCTION

Investigation of the electricity supply and economic growth is not a new area of exploration; it has been extensively researched over the past decades. Nevertheless the results of the causal relationship between electricity supply and economic growth still remain inconclusive (Bouoiyour et al., 2014; Ozturk, 2010; Kula et al., 2012). The findings of some studies (Ghosh 2002; Bayraktutan et al., 2011; Sarker, 2010; Nnaji et al., 2013) suggest that electricity supply Granger-causes economic growth while other studies show that economic growth Granger-causes electricity supply (Smyth and Lean, 2010; Cerdeira, 2012; Bayraktutan et al., 2011).

The policy implications for the knowledge of economic growth and electricity supply nexus has been shown by Yoo and Kim (2006) and Ozturk (2010) to be as follows: Firstly, a one-way causality flowing from electricity generation to economic growth shows that policies for reducing electricity generation should not be

made as they would adversely affect economic growth; secondly, a one-way causality flowing from economic growth to electricity generation shows that policies to reduce electricity could be made without affecting economic growth or could have a small effect; thirdly, no causality between the two would mean that electricity generation could be reduced without affecting economic growth at all. Therefore, it is important to investigate the relationship between these variables to ensure sufficient supply of electricity and enhancement of economic growth.

The existence of these different results motivated the examination of electricity supply-economic growth nexus for the case of South Africa. It also became clear there was no study conducted in South Africa to investigate the relationship between electricity supply and economic growth in South Africa incorporating electricity price, trade openness, capital and labour as the additional variables. The studies carried out in South Africa include; Inglesi-Lotz et al. (2013), Odhiambo (2009), Okafor (2012) and Fei et al. (2014).

Inglesi-Lotz et al. (2013), Fei et al. (2014) and Odhiambo (2009) used electricity consumption and the economic growth nexus instead of electricity supply and economic growth relation in this study. Inglesi-Lotz et al. (2013) and Fei et al. (2014) applied the VAR and VEC models, respectively. The results of these two studies failed to find Granger-causality flowing between electricity consumption and economic growth. Contrary to these Inglesi-Lotz et al. (2013) and Fei et al. (2014), and Odhiambo's (2009) studies revealed bidirectional causality flowing between economic growth and electricity consumption.

Okafor (2012) and Odhiambo (2010) employed energy consumption and economic growth relation instead of electricity supply and economic growth nexus. Odhiambo (2010) applied the Granger-causality test while Okafor (2012) employed Hsiao's Granger-causality test. The results of Odhiambo's (2010) study validated a one-way causality flowing from energy consumption to economic growth while Okafor's (2012) results suggested a unidirectional causality flowing from energy consumption to economic growth.

The studies done in South Africa tend to focus on the bivariate framework, which has been criticised to unreliable results due to omission of relevant variables (Narayam and Smyth, 2005). Therefore, the results from a bivariate framework maybe unbiased. It is against this backdrop that we included electricity prices, trade openness, employment and capital. Trade openness involves the transfer of goods produced in one country to another, either for further processing or for consumption (Shahbaz et al., 2013). Adequate electricity supply is therefore pivotal for the production of these goods being moved from one country to another. Trade openness also has an impact on electricity supply. Since electricity is also a commodity, its production can be made efficient if some of the resources used in its production can be easily moved from one country to another.

Bildirici et al. (2009) argued that the importance of electricity usage is that it improves the quality of life of citizens as well as the quality of industrial production. It can therefore be concluded that increasing the price of electricity will lead to some individual households and industrial consumers not being able to afford it. As a consequence the production of some companies and the quality of life of some household consumers will be compromised. High electricity prices have a negative impact on economic growth (He et al., 2014). From an industry point of view, increasing electricity prices, increases the industrial product costs and sales prices. This will harm competitiveness of this industry in the local and international markets.

Labour has been added as an intermittent variable in most studies because of its positive impact on economic growth and electricity supply. Specifically, Ellahai (2011) and Ghosh (2009) proved that there is a long run relationship between employment, electricity supply and economic growth. Narayan and Singh's (2007) study used energy consumption as a proxy for electricity supply and found that employment Granger causes-economic growth. Narayan and Smith (2005), and Gurgal and Lach (2012) detected a unidirectional causality from electricity consumption to

economic growth and bidirectional causality between electricity consumption and economic growth, respectively. This leads to the expectation of the study's results showing a positive impact of labour on economic growth and electricity supply.

Capital has also proven to have a positive impact on economic growth and electricity supply (Ellahai, 2011). In the studies by Shahbaz et al. (2012) and Adebola (2011), capital was found to Granger-cause economic growth. A feedback hypothesis was also found between capital and economic growth and capital and energy consumption in the study by Lee et al. (2008). It is therefore expected that capital will have a positive and a long term impact on both economic growth and electricity supply in South Africa.

Apart from modelling, this study contributes by investigating the long run relationship between electricity supply and economic growth by employing the autoregressive distributed lag (ARDL) model. The ARDL technique was chosen over the conventional models such as Engle and Granger (1987) and Johansen (1988) for the research for the following reasons (Adebola, 2011): Firstly, the ARDL technique uses a single reduced form of equation to examine the long term relationship of the variables as opposed to the conventional Johansen test that employs a system of equations. Secondly, it is suitable to use for testing co-integration when a small sample data is used. Thirdly, it does not require the underlying variables to be integrated of similar order e.g., integrated of order zero $I(0)$, integrated of order one $I(1)$ or fractionally integrated, for it to be applicable. Lastly, it does not rely on the properties of unit root datasets and this makes it possible for the Granger-causality to be applied in testing the long-term relationships between the variables.

Furthermore, the study used the vector error correction model (VECM) to determine the direction of causality between electricity supply and economic growth. It was chosen for its ability to develop longer term forecasting when dealing with an unconstrained model (Shahbaz et al., 2012). It can also differentiate between long run and short run results. Thus, it can help policy makers to formulate both long run and short run policies accordingly.

The rest of the paper is organised as follows: Section 2 will review the context of South Africa's electricity supply and economic growth. Section 3 will discuss the literature review. Section 4 will focus on the research methodology. Section 5 will present the findings of the research and the last section will conclude the paper.

2. SOUTH AFRICAN CONTEXT

The electricity supply industry in South Africa is managed and controlled by the state-owned monopoly utility, Eskom. Eskom is among the four largest state owned enterprises (SOEs) with Telkom (telecommunications), Transnet (transportation), and Denel (defence production) (Fourie, 2001). South Africa has a long history of depending on the SOEs. The SOEs have contributed significantly to the development of the economy but has been distressed by structural and operational difficulties (Fourie, 2001. p. 205). This has resulted in frequent and unequal patterns of development and an unbalanced service and infrastructure delivery

(Fourie, 2001, p. 205). In 1999, because of the problems caused by their traditional ways of operations and outdated management styles, the government called for the reform of these four SOEs.

The current electricity supply structure in South Africa is illustrated in Figure 1. Eskom has the monopoly of being the sole generator of electricity in South Africa. Figure 1 also shows that the transmission sector is also under full control of Eskom. The distribution sector is dominated by Eskom too, but some distributions are done by the municipalities. This model has been criticised for allowing too much government intervention (Lovei, 2000). This is inefficient because it gives opportunity to special interest groups to utilise the funds earmarked for electricity industry infrastructure development, for their own interests (Lovei, 2000). Furthermore, when government officials are in control, they make decisions knowingly that they will not bare the future consequences as another ruling party would have taken over. Lovei (2000) further showed that this model works against international trade and it also reacts poorly when the economy faces a crisis. This model has cost South Africa its new path growth. For instance, from a study by Wait (2012), it was observed that the country loses approximately 3.3-3.5% gross domestic product (GDP) under the current electricity structure.

The demand for electricity in South Africa has been increasing since the early 1990s (Inglezi-Lotz and Blighaut, 2011). Since democratisation of the country in 1994, the economy underwent significant structural changes. Among these structural changes was electrification for the poor rural areas. Inglezi-Lotz and Blighaut

(2011) showed that 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. The electricity supply did not increase proportionately to the increase in demand.

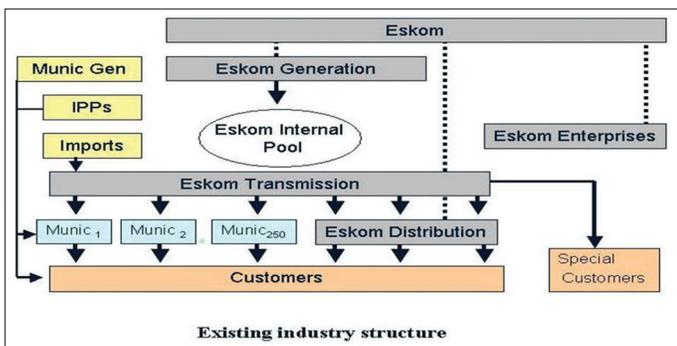
Figure 2 shows the growth rates in the electricity supply and consumption for the period between 1981 and 2011. It can be viewed that electricity consumption has been steadily increasing throughout the period. The country has been experiencing the rise and fall in the electricity generation (Figure 2). 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 low supply of electricity, the department of energy and Eskom resorted to power conservation, increased electricity prices and constructed new power stations. The power conservation policy is harmful to economic growth in a country that is energy dependent (Adebola, 2011). The construction of the new power stations has also costed the nation more than was budgeted. The National Energy Regulator of South Africa (2008) stated that the expected budget for the new expansion was about R343 billion. The construction has been going on for years and to date not even one of the power stations has been completed. The delays in completion of these power stations led to the increase in the budget to fund them. To finance the planned increase in electricity generation, prices had to be increased to meet the cost thereof.

The price of electricity has constantly been increasing following the shortages of supply in 2008. TIPS (2014) showed that availability and cost of electricity play a major role to competitiveness of the firms. Therefore, increasing the cost of electricity hurts the companies' competitiveness and results in closing down of some companies (TIPS, 2014). The economic growth will in return decline.

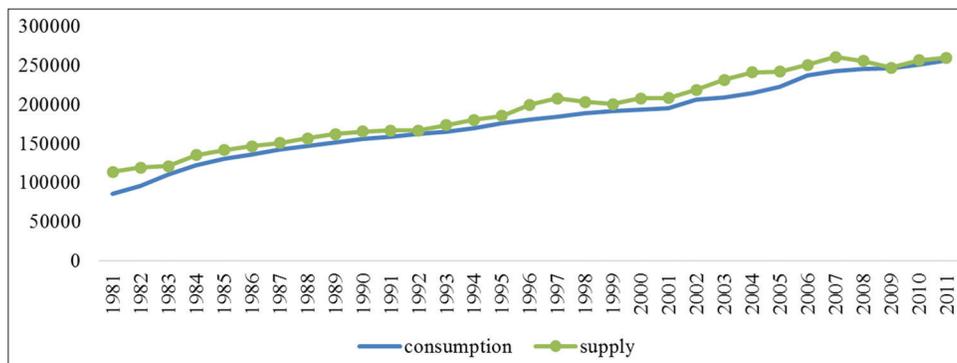
The power outages were foreseen but Eskom did not make significant strides to increase electricity supply timeously. The policies which were implemented costed the industrial, farming

Figure 1: Current South African ESI structure



Source: Eberhard (2002)

Figure 2: Electricity consumption and supply (1981-2011)



Source: Author's Own calculations

and mining consumers' production; while household consumers lost their leisure time (Inglezi-Lotz and Blihnaut, 2011). These views therefore raised many questions for policy makers and the public. What impact did electricity supply and demand imbalance have on economic growth? Do electricity supply and economic growth have a long run relationship? Between economic growth and electricity, which one supersedes the other? Has the termination of the restructuring of the electricity supply industry affected electricity supply? What is the impact of electricity price and trade openness on electricity supply and economic growth?

The primary objective of this research is to examine the co-integration and causality between economic growth, electricity supply, trade openness, electricity prices, employment and capital. The study specifically seeks to determine the causal relationship between economic growth and electricity supply. The study further examines the impact of electricity prices on economic growth and electricity supply; examines the effect of trade openness on electricity supply and economic growth and explores what policy measures will increase electricity supply, based on the research findings.

3. LITERATURE REVIEW

The literature dealing with research of the supply side of electricity supply is sparse. The few studies that considered the supply side attempted to apply the causality framework to indicate which variable takes precedence over the other (Yoo and Kim, 2006). This means that the studies sought to investigate whether electricity supply stimulated economic growth or whether economic growth improved electricity supply.

A bivariate study by Yoo and Kim (2006) investigated the relationship between electricity generation and economic growth. The Indonesian data used in this study was for the period from 1971 to 2002. The findings showed a one-way causality flowing from economic growth to electricity generation without any feedback effect. Thus, in Indonesia the economic growth has led to high income for the citizens, which led to increased electricity consumption from the household sector. Economic growth increases also enhanced the industrial sector's consumption of electricity with the aim of increasing production. This, therefore, has led to more electricity being generated in Indonesia.

Bayraktutan et al. (2011) undertook a study to explore the relationship between electricity generated from renewable resources and economic growth in OECD countries. Their study was based on data covering a period between 1980 and 2007. The empirical results presented a long term relationship between renewable electricity generation and economic growth. The Granger-causality findings revealed a feedback causality flowing between these variables. Therefore, it is important to create policies that support investment in electricity generated from renewable resources as it will lead to an increase in economic growth.

In 2004, Morimoto and Hope undertook a study in Sri Lanka to establish the relationship between electricity generation and economic growth. This study applied Yang's regression analysis to

examine the relationship between these variables. Their empirical results revealed that electricity supply had a positive impact on economic growth in Sri Lanka. It was found that an increase of 1 Mwh of electricity supply leads to Rs. 88 000 to Rs. 137 000 of economic output.

Another bivariate causality study between electricity supply and economic growth relationship was done by Sarker (2010). This study used data from Bangladesh for the period between 1973 and 2006 and applied the VAR model to test for causality direction between the variables. The Granger-causality results indicated that there is one-way causality flowing from electricity supply to economic growth. This implies that there is a need for Bangladesh policy makers to implement policies that will enhance electricity supply. There was no causality found flowing from economic growth to electricity supply and this point to probable poor management of the electricity supply industry.

A trivariate framework study was undertaken by Ghosh (2009) for India. The research investigated the relationship between electricity supply and real GDP using an ARDL bounds testing framework for the period 1970-2006. The results only supported a long term and short-run Granger-causality flowing from real GDP and electricity supply to employment. There was no causality found flowing from electricity supply to economic growth. This implies that energy conservation measures could be implemented in India without affecting economic growth.

Smyth and Lean (2010) undertook a study to investigate the relationship between economic growth, electricity generation, exports and prices. Their results showed no causal relationship between export and economic growth, neither between prices and economic growth. But a unidirectional causality flowing from economic growth to electricity supply was established.

Another multivariate framework study from the supply side was undertaken by Ellahai (2011). The purpose of this study was to determine the impact of electricity supply and industrial sector development on Pakistan's economic growth for the period 1980-2009. Labour and capital were added to Ellahai's (2011) model to form a multivariate system and employ the ARDL bounds test to estimate the co-integration between these variables. The empirical results found existence of both long term and short-run relationships between electricity supply, economic growth, industrial sector development, capital and labour in Pakistan. This shows that the Pakistan government should consider increasing their electricity supply efficiency as an incentive to improve their industrial sector to boost economic growth in Pakistan. It further shows that as more electricity generating plants are build, more people will be employed.

Cordeira (2012) conducted a study to determine the relationship between electricity supply and economic growth incorporating inward foreign direct investment, carbon dioxide emissions from electricity production and population size as additional variables to form a multivariate framework. This study of Portugal employed the bounds testing approach to co-integration and the error correction model for the 1970-2008 period. The co-integration

results revealed long term a relationship between these variables. The Granger-causality results validated the unidirectional causality flowing from renewable electricity production to foreign direct investment in the short term. The results further evidenced bidirectional causality between renewable electricity production, real income, inward foreign direct investment and population.

Chigozie (2013) carried a study to examine the relationship between sustained economic growth and electricity in Nigeria. A multiple regression model is applied in this study to investigate the impact of electricity supply on economic growth development and the impact of supply on industrial development for the period 1970-2010. The results posited that electricity, gross fixed capital formation, industrial production and population are positively related to real GDP per capita.

Chiazoka et al. (2013) undertook a study to evaluate the effect of electric energy supply on the industrial sector productivity in Nigeria covering the period from 1970 to 2010. The study served to determine the extent to which electricity supply impact industrial development and investigate the long run relationship between these variables. It was established that the national energy supply have no significant impact on industrial productivity in Nigeria.

Nnaji et al. (2013) carried out a study in Nigeria to estimate the co-integration and Granger-causality relationship between economic growth, electricity supply, fossil fuel consumption and CO₂ emissions. The study employed data for the period 1971-2009. The empirical findings from the co-integration tests reveal a long term relationship between these variables. Electricity supply is also found to be positively related to CO₂ emissions indicating that there is insufficient supply of electricity in the country. The Granger-causality results revealed that a weak causality existed from electricity supply to economic growth. Therefore, it is important that more investment should be focused toward improving electricity supply in order to enhance economic growth in Nigeria.

Another Nigerian study that focused on the supply side electricity supply was performed by Samuel and Lionel (2013). The study applied the ordinary least squares model in the context of error correction mechanism to examine the relationship between economic growth and electricity supply in Nigeria. The results from the annual time series data revealed that electricity supply is not the only input that significantly affects economic growth in Nigeria but that technology and capital also play a crucial role in economic development. It is recommended that investments should be made towards improvement in technology as this will reduce power outages and ultimately enhance economic growth.

One of the recent studies done in Nigeria on electricity supply was done by Anwana and Akpan (2016). Their study aimed to empirically examine the effects of the power sector reforms on electricity supply covering the period between 1981 and 2015. To form a multivariate frame, electricity prices, government investment in power sector, annual rainfall and per capita GDP

were incorporated as the additional variables. The results validated existence of a long run relationship among the variables.

Khobai et al. (2016) investigated the relationship between electricity supply, economic growth, electricity power outages and employment for South Africa. Their employed quarterly data for the period between 1990 and 2012. The results from the VECM suggested a unidirectional causality flowing from electricity supply to economic growth.

Another study for South Africa was conducted by Khobai et al. (2017) which served to examine the impact of electricity prices on economic growth. This study incorporated electricity supply as one of the independent variables and established that there is a long run relationship between electricity prices, electricity supply and economic growth in South Africa. It established that electricity prices negatively affect economic growth while electricity supply positively affects economic growth.

4. RESEARCH METHODOLOGY

The study uses the extended neoclassical production function where technology is endogenously determined by electricity price and trade openness. The general form of this production function therefore is as follows:

$$GDP = AES^{\alpha_1} K^{\alpha_2} L^{\alpha_3} \epsilon^{\mu} \tag{1}$$

Where, A is technology, GDP is the real gross domestic product, ES is the electricity supply and K, L and ϵ denote real capital, labour and error term respectively. α_1 , α_2 and α_3 represent output elasticity with respect to electricity supply, capital and labour, 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:

$$A(t) = \phi TR(t)^{\alpha} P(t)^{\gamma} \tag{2}$$

Then substituting equation 2 into equation 1

$$GDP(t) = \phi ES(t)^{\gamma_1} TR(t)^{\gamma_2} P(t)^{\gamma_3} K(t)^{\beta} L^{1-\beta} \tag{3}$$

Consistent to the studies by Khan et al. (2012) and Lean and Shahbaz (2012) the series is 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, labour and electricity price become as follows:

$$GDP_t = \alpha_1 + \alpha_{ES} ES_t + \alpha_{TR} TR_t + \alpha_P P_t + \alpha_K K_t + \alpha_{EM} EM_t + \epsilon_t \tag{4}$$

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

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:

$$\text{LnGDP}_t = \alpha_1 + \alpha_{ES} \text{LnES}_t + \alpha_{TR} \text{LnTR}_t + \alpha_p \text{LnP}_t + \alpha_K \text{LnK}_t + \alpha_{EM} \text{LnEM}_t + \varepsilon_t \quad (5)$$

4.1. Data Gathering

Annual data from 1985 to 2014 is employed in this paper. The data on electricity supply and electricity prices is sourced from Statistics South Africa, while South African Reserve bank provided data for economic growth, Trade openness, capital and labour. The series are: economic growth, electricity supply, trade openness, electricity prices, capital and labour. Capital formation is used as a proxy for physical capital while commercial, agricultural and manufacturing employments are used for employment. Trade openness is the taken as sum of imports and exports in nominal terms as a function of GDP.

4.2. Data Analysis

4.2.1. Unit root test

As a first step, the study will undertake unit root tests to determine the stationarity of the variables to avoid spurious results. The Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root tests will be used to test for stationarity.

4.2.2. ARDL model

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., 2009). The research utilises the following UECMs.

$$\begin{aligned} \Delta \text{LnGDP}_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} \text{LnGDP}_{t-1} + \alpha_{ES} \text{LnES}_{t-1} + \\ &\alpha_{TR} \text{LnTR}_{t-1} + \alpha_p \text{LnP}_{t-1} + \alpha_K \text{LnK}_{t-1} + \alpha_{EM} \text{LnEM}_{t-1} + \\ &\sum_{i=1}^p \alpha_i \Delta \text{LnGDP}_{t-i} + \sum_{j=0}^q \alpha_j \Delta \text{LnES}_{t-j} + \sum_{k=0}^r \alpha_k \Delta \text{LnTR}_{t-k} + \\ &\sum_{l=0}^s \alpha_l \Delta \text{LnP}_{t-l} + \sum_{m=0}^t \alpha_m \Delta \text{LnK}_{t-m} + \sum_{n=0}^u \alpha_n \Delta \text{LnEM}_{t-n} + \varepsilon_{1t} \end{aligned} \quad (6)$$

$$\begin{aligned} \Delta \text{LnES}_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} \text{LnGDP}_{t-1} + \alpha_{ES} \text{LnES}_{t-1} + \\ &\alpha_{TR} \text{LnTR}_{t-1} + \alpha_p \text{LnP}_{t-1} + \alpha_K \text{LnK}_{t-1} + \alpha_{EM} \text{LnEM}_{t-1} + \\ &\sum_{i=1}^p \beta_i \Delta \text{LnES}_{t-i} + \sum_{j=0}^q \beta_j \Delta \text{LnGDP}_{t-j} + \sum_{k=0}^r \beta_k \Delta \text{LnTR}_{t-k} + \\ &\sum_{l=0}^s \beta_l \Delta \text{LnP}_{t-l} + \sum_{m=0}^t \beta_m \Delta \text{LnK}_{t-m} + \sum_{n=0}^u \beta_n \Delta \text{LnEM}_{t-n} + \varepsilon_{2t} \end{aligned} \quad (7)$$

$$\begin{aligned} \Delta \text{LnTR}_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} \text{LnGDP}_{t-1} + \alpha_{ES} \text{LnES}_{t-1} + \\ &\alpha_{TR} \text{LnTR}_{t-1} + \alpha_p \text{LnP}_{t-1} + \alpha_K \text{LnK}_{t-1} + \alpha_{EM} \text{LnEM}_{t-1} + \\ &\sum_{i=1}^p \delta_i \Delta \text{LnTR}_{t-i} + \sum_{j=0}^q \delta_j \Delta \text{LnGDP}_{t-j} + \sum_{k=0}^r \delta_k \Delta \text{LnES}_{t-k} + \\ &\sum_{l=0}^s \delta_l \Delta \text{LnP}_{t-l} + \sum_{m=0}^t \delta_m \Delta \text{LnK}_{t-m} + \sum_{n=0}^u \delta_n \Delta \text{LnEM}_{t-n} + \varepsilon_{3t} \end{aligned} \quad (8)$$

$$\begin{aligned} \Delta \text{LnP}_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} \text{LnGDP}_{t-1} + \alpha_{ES} \text{LnES}_{t-1} + \\ &\alpha_{TR} \text{LnTR}_{t-1} + \alpha_p \text{LnP}_{t-1} + \alpha_K \text{LnK}_{t-1} + \alpha_{EM} \text{LnEM}_{t-1} + \\ &\sum_{i=1}^p \theta_i \Delta \text{LnP}_{t-i} + \sum_{j=0}^q \theta_j \Delta \text{LnGDP}_{t-j} + \sum_{k=0}^r \theta_k \Delta \text{LnES}_{t-k} + \\ &\sum_{l=0}^s \theta_l \Delta \text{LnTR}_{t-l} + \sum_{m=0}^t \theta_m \Delta \text{LnK}_{t-m} + \sum_{n=0}^u \theta_n \Delta \text{LnEM}_{t-n} + \varepsilon_{4t} \end{aligned} \quad (9)$$

$$\begin{aligned} \Delta \text{LnK}_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} \text{LnGDP}_{t-1} + \alpha_{ES} \text{LnES}_{t-1} + \\ &\alpha_{TR} \text{LnTR}_{t-1} + \alpha_p \text{LnP}_{t-1} + \alpha_K \text{LnK}_{t-1} + \alpha_{EM} \text{LnEM}_{t-1} + \\ &\sum_{i=1}^p \varphi_i \Delta \text{LnK}_{t-i} + \sum_{j=0}^q \varphi_j \Delta \text{LnGDP}_{t-j} + \sum_{k=0}^r \varphi_k \Delta \text{LnES}_{t-k} + \\ &\sum_{l=0}^s \varphi_l \Delta \text{LnTR}_{t-l} + \sum_{m=0}^t \varphi_m \Delta \text{LnP}_{t-m} + \sum_{n=0}^u \varphi_n \Delta \text{LnEM}_{t-n} + \varepsilon_{5t} \end{aligned} \quad (10)$$

$$\begin{aligned} \Delta \text{LnEM}_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} \text{LnGDP}_{t-1} + \alpha_{ES} \text{LnES}_{t-1} + \\ &\alpha_{TR} \text{LnTR}_{t-1} + \alpha_p \text{LnP}_{t-1} + \alpha_K \text{LnK}_{t-1} + \alpha_{EM} \text{LnEM}_{t-1} + \\ &\sum_{i=1}^p f_i \Delta \text{LnEM}_{t-i} + \sum_{j=0}^q f_j \Delta \text{LnGDP}_{t-j} + \sum_{k=0}^r f_k \Delta \text{LnES}_{t-k} + \\ &\sum_{l=0}^s f_l \Delta \text{LnTR}_{t-l} + \sum_{m=0}^t f_m \Delta \text{LnP}_{t-m} + \sum_{n=0}^u f_n \Delta \text{LnK}_{t-n} + \varepsilon_{6t} \end{aligned} \quad (11)$$

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 6 to 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:

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

versus

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

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).

4.2.3. VECM granger causality

VECM Granger causality will be used to determine the causality between the variables. The error correction model works in a way that the error in the previous period reviews the correction toward long run equilibrium (Jamil and Ahmed, 2010). It was chosen for its ability to develop longer term forecasting, when dealing with an unconstrained model.

The information pertaining to long run relationship between the variables is contained in the ECT while the short run information is determined by the lagged terms of individual coefficients (Adebola, 2011). Adebola (2011) further showed that the long run relationship is depicted by a negative sign on the coefficient of the ECT. The VECM in the six variables case can be presented as follows:

$$\begin{aligned} \Delta LGDP_t = & \alpha_{10} + \sum_{i=1}^q \alpha_{11} \Delta LGDP_{t-i} + \sum_{i=1}^r \alpha_{12} \Delta LES_{t-i} + \\ & \sum_{i=1}^s \alpha_{13} \Delta LTR_{t-i} + \sum_{i=1}^t \alpha_{14} \Delta LP_{t-i} + \sum_{i=1}^u \alpha_{15} \Delta LEM_{t-i} + \\ & \sum_{i=1}^v \alpha_{16} \Delta LK_{t-i} + \psi_1 ECT_{t-1} + \varepsilon_{1t} \end{aligned} \tag{12}$$

$$\begin{aligned} \Delta LES_t = & \alpha_{20} + \sum_{i=1}^q \alpha_{21} \Delta LES_{t-i} + \sum_{i=1}^r \alpha_{22} \Delta LGDP_{t-i} + \\ & \sum_{i=1}^s \alpha_{23} \Delta LTR_{t-i} + \sum_{i=1}^t \alpha_{24} \Delta LP_{t-i} + \\ & \sum_{i=1}^u \alpha_{15} \Delta LEM_{t-i} + \sum_{i=1}^v \alpha_{16} \Delta LK_{t-i} + \psi_2 ECT_{t-1} + \varepsilon_{2t} \end{aligned} \tag{13}$$

$$\begin{aligned} \Delta LTR_t = & \alpha_{30} + \sum_{i=1}^q \alpha_{31} \Delta LTR_{t-i} + \sum_{i=1}^r \alpha_{32} \Delta LGDP_{t-i} \\ & + \sum_{i=1}^s \alpha_{33} \Delta LES_{t-i} + \sum_{i=1}^t \alpha_{34} \Delta LP_{t-i} + \\ & \sum_{i=1}^u \alpha_{35} \Delta LEM_{t-i} + \sum_{i=1}^v \alpha_{36} \Delta LK_{t-i} + \psi_3 ECT_{t-1} + \varepsilon_{3t} \end{aligned} \tag{14}$$

$$\begin{aligned} \Delta LP_t = & \alpha_{40} + \sum_{i=1}^q \alpha_{41} \Delta LP_{t-i} + \sum_{i=1}^r \alpha_{42} \Delta LGDP_{t-i} + \\ & \sum_{i=1}^s \alpha_{43} \Delta LES_{t-i} + \sum_{i=1}^t \alpha_{44} \Delta LTR_{t-i} + \\ & \sum_{i=1}^u \alpha_{45} \Delta LEM_{t-i} + \sum_{i=1}^v \alpha_{46} \Delta LK_{t-i} + \psi_4 ECT_{t-1} + \varepsilon_{4t} \end{aligned} \tag{15}$$

$$\begin{aligned} \Delta LEM_t = & \alpha_{50} + \sum_{i=1}^q \alpha_{51} \Delta LEM_{t-i} + \sum_{i=1}^r \alpha_{52} \Delta LGDP_{t-i} + \\ & \sum_{i=1}^s \alpha_{53} \Delta LES_{t-i} + \sum_{i=1}^t \alpha_{54} \Delta LTR_{t-i} + \\ & \sum_{i=1}^u \alpha_{55} \Delta LP_{t-i} + \sum_{i=1}^v \alpha_{56} \Delta LK_{t-i} + \psi_5 ECT_{t-1} + \varepsilon_{5t} \end{aligned} \tag{16}$$

$$\begin{aligned} \Delta LK_t = & \alpha_{60} + \sum_{i=1}^q \alpha_{61} \Delta LK_{t-i} + \sum_{i=1}^r \alpha_{62} \Delta LGDP_{t-i} + \\ & \sum_{i=1}^s \alpha_{63} \Delta LES_{t-i} + \sum_{i=1}^t \alpha_{64} \Delta LTR_{t-i} + \\ & \sum_{i=1}^u \alpha_{65} \Delta LP_{t-i} + \sum_{i=1}^v \alpha_{66} \Delta LEM_{t-i} + \psi_6 ECT_{t-1} + \varepsilon_{6t} \end{aligned} \tag{17}$$

Where ε_{it} (for $i = 1, 2, 3, 4, 5, 6$) represent serially uncorrelated random error terms. ECT_{t-1} (error correction term) represent the co-integrating vectors. ψ denotes the adjustment coefficient and shows how much disequilibrium is corrected (Jamil and Ahmed 2010). "The size and statistical significance of ECT is a measure of extent to which the left hand side variable in each equation returns in each short-run period to its long-run equilibrium in response to random shocks" (Jamil and Ahmed 2010:6020). This makes the error correction model more powerful over Standard Granger causality and Sims tests because it comes up with channels of identification which would not be realised by these two tests. Hence this study adopted the error correction model. The tests for causality can be derived from the equations 12-17 above as follows:

From equation 6, the causality from ES, TR, P, EM, K to GDP can be tested. For example to test the joint significance of lags α_{12} , α_{13} , α_{14} , α_{15} , and/or α_{16} indicate that there is causality flowing from ES, TR, P, EM and/or K to GDP. The significant Chi-square

Table 1: Results for unit root tests

Variables	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, ADF: Augmented Dickey Fuller, GDP: Gross domestic product

statistics for joint tests on coefficients of lagged variables shows that there is a short run causality flowing from the independent variable(s) to the dependent variable (Jamil and Ahmed 2010). To find the long run causality flowing from the dependent variable(s) to the dependent variable, the coefficient of the error correction term (ψ) should be significant.

5. 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.

5.1. Co-integration Test

The results for the ARDL bound test, based on Narayan (2005) are illustrated in Table 2. 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 2). When economic growth, electricity prices and employment are used as dependent variables, co-integration is established. This is because their F-statistics 4.10, 4.88 and 8.05 are greater than the upper critical bound value of 3.625 at 5% level of significance. 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 elasticities are reported in Table 3.

The results exhibit that electricity supply has a long run positive effect on economic growth and it is significant at 1% level of significance. All else the same, a 1% increase in electricity supply is expected to increase economic growth by 3.94%. The results are

Table 2: F-statistics for co-integration

K	Critical value bound of the F-statistic					
	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, p. 470). Source: Author’s Own calculations

Table 3: Long run analysis

Dependent variable=LnRGDP			
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-squared	0.45		
F-statistics	4.05*		
DW test	1.64		

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

in line with the findings of Ellahai (2011) 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 and 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.

Table 3 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 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).

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 Khan et al. (2012).

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 3 and 4 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 3 and 4 illustrate that the graph of the test lie between the upper and lower critical limits.

5.2. VECM Granger-causality

The VECM was employed to find the Granger-causality between electricity supply and economic growth. Table 4 demonstrates the results for the long-run and short-run Granger causalities, respectively. The results in Table 4 present the coefficient of the lagged error term which is used to determine the existence of the long run causality between the variables. The coefficient of the lagged error term shows the speed of adjustment of the endogenous variables to explanatory variables and determines the long run causality.

The findings of the tests on causality are presented in Table 4. The short run results failed to demonstrate a short run causality

Figure 3: Plot of cumulative sum of recursive residuals

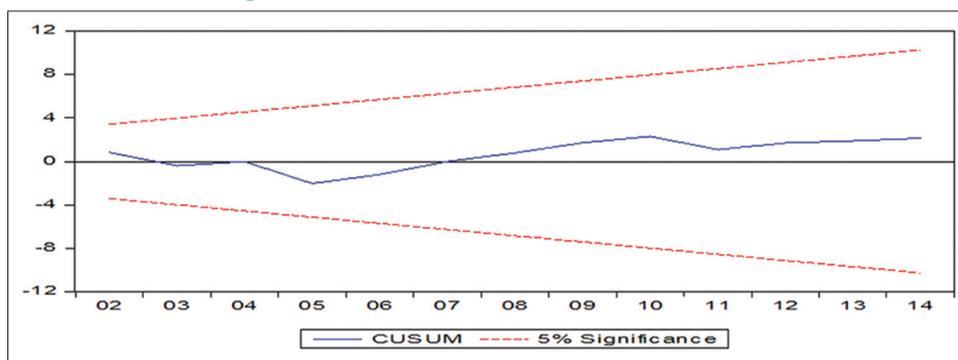


Figure 4: Plot of cumulative sum of squares of recursive residuals

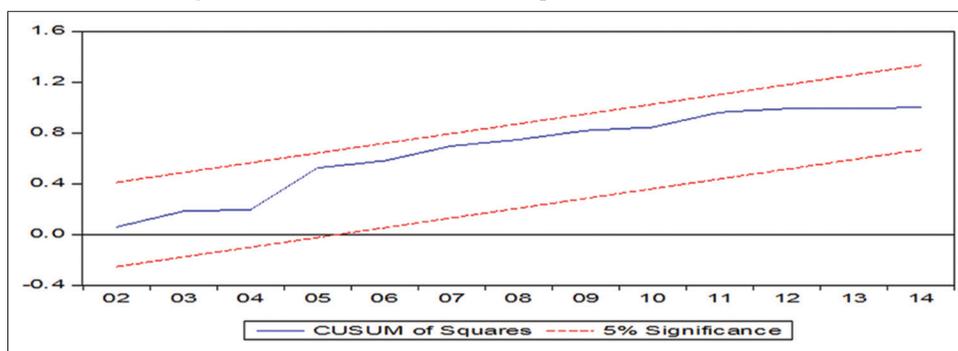


Table 4: Vector error correction results

Dependent variable	Type of causality						Long-run ECT_{t-1}
	Short run			Long-run			
	$\Sigma \Delta \ln GDP$	$\Sigma \Delta \ln ES$	$\Sigma \Delta \ln TR$	$\Sigma \Delta \ln P$	$\Sigma \Delta \ln EM$	$\Sigma \Delta \ln K$	
$\Delta \ln GDP$		0.1127 (0.0564)	0.4505 (0.2252)	1.5911 (0.7956)	1.2233 (0.6116)	0.3878 (0.194)	-1.503**
$\Delta \ln ESS$	3.3569 (1.6778)	-	2.5455 (1.2726)	15.227* (7.6140)	3.1484 (1.5742)	6.542** (3.271)	-0.621***
$\Delta \ln TR$	2.1500 (1.0750)	1.0844 (0.5222)	-	34.384* (17.197)	4.0605 (2.0302)	3.5419 (1.774)	-0.367
$\Delta \ln P$	17.539* (8.7695)	1.6099 (0.8050)	23.827* (11.913)	-	28.549* (14.275)	0.3333 (0.167)	0.145*
$\Delta \ln EM$	36.934* (18.467)	2.4575 (1.2287)	7.648** (3.8239)	24.093* (12.046)	-	1.5816 (0.791)	0.476*
$\Delta \ln K$	0.3296 (0.1648)	0.2566 (.01283)	0.6604 (0.3302)	1.5856 (0.7928)	0.0921 (0.0460)	...	-0.664

Source: Author's Own calculations

flowing from electricity supply, trade openness, electricity prices, employment and capital formation to economic growth. There was no short run causality flowing from economic growth, trade openness and employment to electricity supply either. The absence of a short run causality flowing from electricity supply to economic growth imply that environmentally friendly policies like electricity conservation, the demand-side management policies and efficiency improvement measures, can be implemented without adversely affecting economic growth.

The coefficient of the lagged error term was found to be negative and significant in equation six. This implies that there is a long run Granger-causality flowing from electricity supply to economic growth. Moreover, there is existence of another Granger-causality running from economic growth to electricity supply because the coefficient of the lagged error term for equation seven is negative and significant. Thus, according to the overall results, there is bidirectional causality flowing between economic growth and electricity supply in South Africa. This implies that enhancing economic in South Africa is propitious for the improvement of the electricity supply industry which in turn assists to boost economic growth.

The VECM results further demonstrated that trade openness Granger-causes both electricity supply and economic growth. This means that over time higher levels of trade openness can give rise to economic growth and electricity supply. The link between electricity supply, economic growth and trade is based on the idea that exports require more production, hence more electricity supply. Imports, which involves more transportation, machinery and luxury goods will demand more electricity, as a result, more electricity will be generated.

It was further established that electricity prices, employment and capital formation Granger-cause economic growth and electricity supply in the long run. This implies that South Africa, being a highly energy dependent country will have the performance of its labour and capital partly determined by sufficient electricity. Electricity prices should also be affordable as they play a huge in the growth of the economy and the development of electricity supply sector.

6. CONCLUSION AND POLICY RECOMMENDATIONS

The paper employs the extended Cobb-Douglas production model to determine the direction of causality among electricity supply, trade openness, electricity prices, employment, capital and economic growth, using the South African annual data from 1985 to 2014. The ARDL model was employed to determine the long run relationship between the variables. To establish the direction of causality among the variables, the VECM Granger-causality was applied.

The ARDL bounds technique results showed that there is a long run relationship between electricity supply, economic growth, trade openness, electricity prices, employment and capital. The

findings of the VECM model suggested that there is no short run causality flowing either from economic growth to electricity supply or from electricity supply to economic growth. The long run results on the other hand suggests a feedback relation flowing between economic growth and electricity supply. The different Granger-causality results between the long run and short suggest that the policy makers in South Africa ought to draft different policies at different time frames.

The absence of a short run causality running from electricity supply to economic growth implies that the electricity conservation policies can be implemented without adversely affecting economic growth in South Africa. The policies aimed at reducing wastage of electricity such as demand-side management and efficiency improvement measures can be implemented in the short run and will not cause harm to economic growth. But the long run results indicating a bidirectional causality flowing between electricity supply and economic growth demonstrate that electricity conservation policies cannot be applicable in South Africa in the long run as they will adversely affect economic growth. Therefore, to ensure security of supply to meet the demand of electricity, it is important for the policy makers to explore the alternative sources of electricity such as renewable energy sources (wind, hydro and solar).

The findings further portray an existence of a long run causality flowing from trade openness, electricity prices, employment and capital to economic growth and electricity supply. Therefore, since South Africa is an electricity dependent country, performance of some factors of production like labour and capital will partly be determined by sufficient supply of electricity. It is also important that the country ensure free trade as this will ensure that South Africa benefits from high technology input from other countries.

The overall findings of this paper validates that electricity supply stimulates economic growth in South Africa. Intuitively, improvement in electricity supply is a necessity for enhancement of the economy. It is therefore, necessary to ensure secure, reliable, efficient, clean and sustainable electricity in the country. Therefore, the government and policy makers should also put in place the restructuring of the electricity supply industry. This will lead to more supply of electricity as more players will be allowed entry into this industry.

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