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Article

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The Electricity Security in South Africa: Analysing Significant Determinants to the Grid Reliability

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ABSTRACT

South Africa has been suffering from low electricity supply for decades now, dating back to the first occurrence during 1983. Another crisis struck by the fall of 2007, which shocks from the crisis still affect the economic growth. The country's fossil fuels, which serve as a major contributor to its electricity generation, are depleted by 1% every year. Other determining variables such as increases in domestic consumption and industrial intensity as domestic and industrial consumption rise, increase in coal prices, drop in the production volumes of coal, depreciation in machinery remain continuous dangers to the future reliability of supply of the grid. This has led to inflation of consumer prices, whilst end users' future access to adequate electricity supply is not guaranteed. This paper aimed at determining the steadfastness of the South African electricity grid in meeting consumers' demands. A quantitative research design was employed. A multiple time series research method utilising secondary data from key determining variables to electricity supply from the first quarter of 1998 to the last quarter of 2015 was employed in this study. The Eviews statistical software was employed to obtain regression probabilities through the multiple ordinary least square model specifications. The Engle-Granger approach was used to establish whether or not co-integration exists between the independent and the dependent variables. The co-integration analysis reflects that there is a significant long-term relationship between the independent and the dependent variables.

Keywords: Electricity Security, Supply Determinants, Grid Sustainability
JEL Classification: Q47

1. INTRODUCTION

Winkler (2006a. p. 23) notes that energy has been a very instrumental feature in shaping the South Africa economy. Supplying consistent electricity to the mining industry, to boost economic growth was the primary supply objective of the public sector throughout the early quarters of the twentieth century. The intensive dependence on the imported energy resources raised concerns about energy security during the 1950s. The government of the time initiated projects to meet the demand for electricity by constructing massive power stations in the 1960s and 1970s. The previous abundant electricity reserves are gradually getting exhausted. A major concern as viewed by Winkler and Marquand (2009) is that international standards currently rank the South African economy extremely energy intensive.

Hameed and Khan (2016) say electricity is prime on the hierarchy among energy resources of priority for every modern economy. It is essential for an economy to generate and distribute a sufficient supply of electricity if sustainable economic growth is to be attained (Kohler, 2013. p. 5). Ojeaga et al. (2014) states that issues about energy sustainability should be of paramount importance to every economy since it mostly determines the possibility of economic growth and productivity. Kohler (2013. p. 5) alludes that the availability and reliability of energy is an important determinant of economic productivity. Conceptualising energy security differ depending on the perspective taken, ranging from the international to regional, national to local, and also differ across stakeholders such as industry, communities and individuals (Chester, 2010). This paper views that, it is of core importance to evaluate the security of electricity supply in South Africa, considering recent low supplies caused by influential determinates to electricity production and supply.

Hedden (2015. p. 7) agrees that South Africa's electricity demand currently exceeds supply. Von Keltehodt and Wocke (2008) note that if electricity demands exceed supply, the cost and the unreliability of electricity supply increases. Hameed and Khan (2016) assert that an electricity grid is under siege if production potentials are not comparative to the constantly increasing demands of the industrial and domestic sectors. This paper seeks to call attention to the responsibility of supply security in the electricity market and to demonstrate the most effective parameters that can be incorporated as the standards for measuring the security of supply.

The problem in this paper relates to electricity security in South Africa that is threatened by elements that significantly determine electricity production and supply. The increasing pressure of demand over supply reflects the unsustainability of over-reliance on coal technology reflecting a potential threat to future electricity security. There is a limited policy advancement towards significant electricity security in South Africa.

2. LITERATURE REVIEW

The following section discusses energy security, South Africa's grid security and factors that have been considered as influencing variables.

2.1. Energy Security

Knox-Hayes et al. (2013) agree that security and reliability of energy have become increasingly important in energy policy debates, driving an agenda towards a change in energy systems. Chester (2010) notes that there has been little discussion of the notions which underpin the meaning of the term "energy security." As a result, it is often referred to as the threats to a continuous supply of energy resources, failing infrastructure and depletion of energy resources. Consequently, these risks lead to price hikes and shortages, initiating a negative impact on demand. Recently, researchers in the field of energy have been creating awareness on the dangers of poor energy security. Burgess and Nye (2008) agree that a diminished "energy security" is primarily experienced through fuel deficiencies resulting in electricity cuts, as well as increases in the price for power.

Glyn et al. (2014) conducted a study on the energy security of Ireland and revealed findings that Ireland's electricity grid is very vulnerable due to: Import dependency by 88% of its energy requirement, it's limited energy mix and wobbly pricing. Glyn et al. further forecast that Ireland will encounter possible disruptions in electricity supply if strategic implementations are not established soon enough. Demski et al. (2014) say in the United Kingdom (UK), there is a proposal from the general public for a change in the energy system that is solely dependent on gas to more advanced 21st century energy generation technologies. High concerns regarding the dependence on fossil fuels, high imports of energy resources to more immediate issues ranging from insufficient reserves to meet demand and price increases has relatively low concerns for possible disruptions to electricity supply.

Reverting to electricity security, Raillon (2010. p. 2) notes that there is no common definition of electricity supply security. Electricity supply security can be attributed to the capability of an electricity grid in meeting up the electricity needs of final consumers with a defined quality and at a transparent and cost-oriented price. In line with afore context, electricity security is the capability of an electrical system to supply electricity to consumers with a definite level of continuity and quality in a sustainable manner, according to generally acceptable delivery standards (Gábor and Lipponen, 2006. p. 6).

2.2. South African Electricity Grid Security

Clark et al. (2005. p. 29) maintain that the effective provision of electricity services to consumers significantly depends on price and supply reliability. Thus, security of electricity is threatened if the physical quantity of available electricity is insufficient and prices that are not affordable for consumers. Clark et al. (2005. p. 13) emphasise that assessing and improving on the security of supply to meet future demand has always been a primary agenda for power sectors reform in South Africa. Wilson and Adams (2006. p. 5) note that the rate of growing insecurity of supply in the South African electricity industry is a major challenge to suppliers. Wilson and Adams allude that a major threat to supply security is the inadequate generation of required capacity that is secure enough to deliver power to all regions of the country. Ojeaga et al. (2014) extensively evaluate constraints to energy security ranging from the availability of natural resources for a generation, size of regions, regional temperature level, income, population density, cost of accessing energy, consumption demands both domestic and industrial and spend on technology. Threats that were identified as a matter of concern to energy security include; the cost of accessing energy, availability of natural resources for a generation, domestic and industrial electricity consumptions.

In accord with Newberry and Eberhard (2008. p. 10) neither the Department of Energy (DOE), Eskom nor National Energy Regulators South Africa (NERSA) has ever critically looked into the country's supply security nor set standards establishing a procedure for measuring electricity security in South Africa. Wilson and Adams (2006. p. 6) state that, in the past, Eskom mostly utilised the criterion of determining the cost of unserved energy, which is assumed to represent the value to customers of system security. Previously, this approach has been widely used in most countries but is now recognised as not being an adequate basis for determining power system security. Wilson and Adams (2006. p. 5) have the viewpoint that variables that impact on the reserve margin is probably the most appropriate deterministic criterion to factors that pose a threat to the South African grid security.

Determining the security of an electricity grid involves the complexity of assessing the proper functioning of its independence to its dependent factors. The focus of this paper is about factors that cause a significant interruption to electricity supply with a material consequence. There might be many aspects that affect the security of electricity supplies in South Africa. However, this paper focuses primarily on aspects of fossil fuel, supply price, consumption growth and depreciation on machinery. That is not to say other elements are inferior, but to specify that, after an extensive review of the literature, the mentioned variables significantly determine the occurrence of a threat to the South Africa electricity grid.

2.3. Coal Energy

Focusing mainly on coal electricity generation and not from all energy sources, in general, is because the energy sector is too diverse for comparative analysis. South Africa's electricity generation is 95 percent dependent on coal. An intensive investment in coal energy assets has historically been the country's electricity development path (Kohler, 2013. p. 2).

Antin (2013. p. 6) posits that the South African mining industry seems well-established, but a closer inspection reveals severe productivity issues. Prevost (2003. p. 102) points out that the coal sector has reached its threshold and will soon experience stagnation. Coal production is at a recession as output and exports steadily decrease. Prevost alluded that 2020 is the "target year" when most coal factories might have shut-down and reserves will be close to attaining exhaustion.

British Petroleum (BP) Statistical Review of World Energy (2005. p. 30) version estimated South Africa's coal reserve is at 5.4% of the world's total, matching up the Department of Minerals and Energy evaluation of 31 Metric Tons (Mt) by 2005. BP Statistical Review of World Energy (2016. p. 30) state that the South African coal reserves are constantly at a decrease, with current levels estimates at 3.4% of the world's total. Fourie (2009. p. 1) stated that, despite that the Waterberg coalfields are expected to cater for future crisis, it is dangerous to rely on, since estimates of its total quantity of resources are highly uncertain as it has been relatively under-explored. Jeffrey (2005) and Fourie et al. (2009. p. 28-29) maintain that the current estimations of the Waterberg fields predict low productivity. It is also endangered by some geological setbacks from past tectonic activities with no guarantee of effective exploitation of the Waterberg coal deposits.

Baxter (2015. p. 19) points out that a decline in productivity adds to the headwinds of the industrial progress as a capital injection from activities such as coal exports dropped due to reduced volumes of production. Antin (2013. p. 1) highlights that the mining industry has undergone a major unrest since the beginning of the 2008 global financial crisis, with workers inter-alia demanding better wages. Antin posits that 2012 experienced a fast decreasing productivity prior to turmoil by mineworkers. Altman (2013. p. 6) notes that poor management of available coal stocks adds to the challenges to attaining coal adequacy for the electricity industry.

Mayet et al. (2012. p. 3-4) view that Eskom believes it can use coal resources as a competitive advantage to improve production capacity failed to consider the implications of future coal prices (CPs). Prices of coal at present are on a constant increase and very unstable. There is anticipation that situations will get worse in the future. Mayet et al. (2012. p. 4) says pricing is furthermore challenged by the competition of the Broken Hill Proprietary Billiton group, which controls the largest coal produced in South Africa. An estimated US$800 billion is required by Eskom to acquire Billiton coal deposits. A pricing agreement does not seem to entirely reflect the interests of the public as Eskom's agenda is towards protecting its monopoly as primary administrator to energy resources. In South Africa, CPs are mostly a 25–30% of the electricity consumer price since CP variations are highly reflected in the electricity production cost (Inglesi, 2010).

2.4. Consumer Price of Electricity

Inglesi and Pouris (2014. p. 1) say there have been continuous debates on whether increases in electricity tariffs will affect the energy sector and if it is necessary. Altman (2013. p. 6) maintains that there are similar consistent debates as to whether South Africa's protocol for the consumer electricity price increase is effectively aligned to global standards. Kohler (2013. p. 5-6) states that South African electricity regulators technically determine electricity prices, instead of the forces of demand and supply in the market. Kohler further views that the absence of an appropriate pricing determination instrument is likely to cause imbalances in the demand and supply, particularly in cases when regulators are not well experienced in responding to market signals. Eskom (2012. p. 5) states that the South Africa pricing technique follows a multi-year price determination (MYPD), in which Eskom applies to NERSA for a periodic electricity price adjustment plan. Altman (2013. p. 6) agrees that the electricity selling price should reflect its full production cost. Alternatively, the ongoing proposals for multiple inflation type increases that are currently discouraging global investment in South Africa, is not realistic. Thopil and Pouris (2013) performed an empirical research study of the state of electricity consumer price in South Africa and the following outcomes were ascertained:

- The industrial sector is under-priced while the residential sector suffers immensely from high percentage increases. This was questionable as to why price increases are not equally executed on both sectors considering that their benefits are not proportionate.
- Multi-year pricing determination (MYPD) has been seriously criticised to be a non- pragmatic pricing technique. MYPD has a history of unfairness traced from the prevailing electricity pricing inequality in South Africa. Thopil and Pouris suggest that a more appropriate standard that would ensure transparency in all sectors should be introduced.

Mayet et al. (2012. p. 5) confirm Eskom agrees that the MYPD makes it too complicated to establish a 100% precise cross-subsidy plan from industrial to residential users. Such finding is proof enough to introduce a new tariff structure that will guarantee electricity accessibility to the poor. Mayet et al. allude that Eskom's decision to apply the MYPD approach, instead of exploring a more appropriate and reliable alternative can be attributed to Eskom's managerial convenience policies.

Alternatively, literature points out that price is a very complex variable to conclude electricity tendencies in South Africa. Blignaut et al. (2014) conducted a comparative investigation to assess the elasticity of electricity price for years, 2002–2011 in South Africa. Outcomes from empirical research found a statistically insignificant elasticity for periods pre-2007 agreeing with over 90% of similar studies. Alternatively, post–2007 results were statistically significant across 9 out of 11 sampled sectors. Policy implications point out that tariff restructuring might influence future consumer behaviour and might be a significant threat to electrification potentials. Inglesi and Pouris (2014. p. 1) carried out a similar investigation evaluating the causality of price and income on electricity demand in South Africa with similar findings. Inglesi (2011) view that price is becoming relatively weaker over the years as a perfect explanatory variable for electricity consumption tendencies. A consensus regarding the significance of electricity price as a determinant to electricity tendencies in South Africa is currently in a dilemma due to conflicting findings from researchers.

2.5. Consumption Growth

Marquard et al. (2008) note concerns on the implications of the steady increase in population growth. These increases result in roughly 350 000 new South African households per year. The annual growth in household formation is a primary challenge on the electricity grid. Hameed and Khan (2016) agree that there is a significant positive relationship between population growths, which consequently caused a drastic change in electricity consumption. The South African Energy Efficiency Report (2011. p. 2) points out that South Africa has high energy consumption per capita of 2.7 averages, compared to the regular global consumption of 1.8 average. Energy consumption between 1990 and 2002 increased by 1.1% yearly; after 2002, increases have been at a very rapid rate of 4% yearly.

Kohler (2013. p. 2) highlights that there has been a constant growth in electricity consumption and intensity in South Africa from 1971, implying that the South African electricity efficiency instruments are not implemented effectively based on the required international standards. Inglesi and Blignaut (2011. p. 4) maintain that the constant increase in grid electricity consumption in South Africa is prior to major transformation programmes. According to Kohler (2013. p. 2), electricity transformation programmes such as historically low prices initiated a substantially low electricity efficiency environment relative to other countries. Winkler and Marquand (2009) say electricity efficiency implementation in the industrial sector is still significantly poor and considerably lower than global averages.

Hedden (2015. p. 5) says the Council for Scientific and Industrial Research modelled and forecast that the energy intensity of the South African economy will decrease over time. The underlying logic behind the model assumption is on the basis that South Africa is transitioning away from energy-intense industries to a more service-oriented economy. Hedden disagrees that it is not completely factual since as the country demands for electricity increases as well. This means that, even if the energy intensity of the country decreases, the size of the economy is also growing the overall energy consumption.

3. RESEARCH METHODOLOGY

The research methodology of this paper was a quantitative research design. A quantitative design was the most appropriate approach because analyses had to take account of occurrences of behaviour between tested variables and to record correct answers and errors in quantity. The research technique was the multiple time series approach. Schmidheiny (2016. p. 2) defines a multiple linear regression models as a linear relationship between a dependent variable and a set of explanatory variables. According to Mohod (2012) the independent variable is the variable which researchers measure while the dependent variable is the assumed effect. Data for the empirical investigation was collected from secondary sources. All data was retrieved from Quantec South Africa. The data gathering process involved obtaining time series data of sampled variables. Data was categorised into 1 dependent variable (electricity production) and 4 independent variables (electricity price, CP, coal production, electricity consumption and depreciation of machinery).

Empirical research was affected by the non-availability of data for depreciation of machinery as scheduled to be part of the empirical research. The factor was eliminated from the empirical research since even an appropriate proxy could not be ascertained. Data frequency was all on a quarterly basis for both the dependent and the independent variables. The study period was considered from the first quarter of 1998 to the last quarter of 2015. All variables produced 68 individual observations. The only exception was the electricity price with an observation of 63 since there was no data available from the first quarter of 1998 to the last quarter of 2002. Information obtained was used to determine regressions' effects of the dependents over the independent variable. The dependent variable (electricity production) was measuring the electricity supply security such as disruptions should production decline (grid reliability). The independent variables measured the impact on electricity production. The total number of observation occurrences accumulate to 471.

3.1. Hypotheses

The hypothesis is a good guess at the best answer to a question, based on the most reliable facts available (Chesterman, 2008. p. 10). Bulajic et al. (2012) assert that a hypothesis condenses the general focus of empirical research to aid research framework or model. A hypothesis is mostly designed to prove false than prove true because it is not possible to test all the viable combinations and conditions that a hypothesis can cover (Bulajic et al., 2012). Levine et al. (2008) agree that testing the significance of the null hypothesis is the most common method that is applied to a statistical inference research. To develop an effective and applicable model for the empirical research, hypotheses were developed to guide model construction by the following assumptions:

1. If the production of coal decreases, electricity supply capacity will decrease.
2. If electricity prices increase, electricity supply capacity will increase.
3. If CP increases, electricity supply capacity will decrease.
4. If the increase in consumption is not relative to production, supply capacity will decrease.

3.2. Model Specification

The ordinary least square (OLS) model was employed in performing linear regressions. Varmuza and Filmer (2009. p. 124) state that multiple linear regressions can utilise the OLS model. A multiple OLS model is denoted as follows:

$Y_t=\beta_o+\beta_1X_{1t}+\beta_2X_{2t}+\beta_3X_{3t}+\beta_4X_{4t}+\varepsilon_t$ (Formula 1)

Concerning formula (1) indications represented are as follows:
Y_t=Dependent variable.
βo=The intercept of the equation.
β_{1-4}=The slope coefficient of the independent variables.
X_{1t-4t}=The independent variable that is used to predict the dependent variable.
ε_t=The error term.

The error term. The slopes all convey information about the conditioned association between an independent variable and the dependent variable. Conditioned association, for instance, means: β_1 is the association between X_1 and Y_1 holding X_2-X_4 constant.

The model specification (causality between the dependent variable to independent variables) of this paper was then equated as:

$EPVt=\beta_o+\beta_1EPR_t\beta_2CV_t\beta_3CP_t\beta_4ECI_t+\varepsilon_t$ (Formula 2)

Concerning formula (2) indications represented are as follows:
EPV=Electricity production volumes.
EPR=Electricity consumer price.
CV=Coal production volumes.
CP=Coal price.
ECI=Electricity consumption intensity.
β_o=The intercept of the equation.
$\beta 1$-β_4=The slope coefficient of the independent variables.
ε =The error term or white noise. The error term includes other variables that can also influence on EPV.
t =The sampled period.

The OLS was seen to be the best suited and most robust model specification in acquiring the objective of this paper.

4. ANALYSES AND DISCUSSION

The multiple time series was the analytical approach used in this paper. Varmuza and Filmoser (2009. p. 124) state that a multiple linear regression time series measures a single Y variable with several X variables. A multiple time series analysis was superlative in conducting the research analysis as it simultaneously considers the dependent variable to a range of possible independent variables that can significantly affect the dependent variable. It was the most appropriate technique to effectively attain a reliable outcome to the objective of this paper. Neuman (2014. p. 421) states that a very important element of the multiple regression is that it has been recognised by most time series researchers, as an effective approach in confirming the accuracy predictions between the independent or control variables over the dependent variable through the R-squared.

The objective was to assess the level to which significant electricity production determinants are increasingly negatively affecting electricity security of supply in South Africa. Because all variables had their measurement, they had to be logged to make them all similar to avoid permeability. To draw an applicable and reliable conclusion to assumed hypotheses, different time series regression tests were performed. Tests were performed in a systematic order as follows: Unit root tests, model estimation tests, Jansen co-integration, Granger causality and the diagnostic tests. A summary of tests conducted is reflected in Table 1.

Results were interpreted according to the outcomes from regressions. Results were accurately interpreted to avoid any possibility of fallacy in the analysis. All the time series data tests as indicated were done strictly and all procedures followed. The P-value is the most important element from regression results. This is because it determines the probability of whether the null or the alternative hypothesis is to be rejected or not. Performed tests seek for a $P < 0.05$ in order not to reject the null hypothesis. Likewise, the alternative hypothesis is accepted if the $P > 0.05$. The rule is different for the normality and serial correlation and the heteroscedasticity tests (diagnostic tests). The diagnostic tests require a $P > 0.05$ to establish that regression residuals are normally distributed and not serially correlated. Alternatively, residuals are considered to be abnormal distributed and serial correlated if results are <0.05. The p-values are marked as (*), (**) and (***) to denote significance levels at 10%, 5% and 1% respectively. It should also be noted that results were rounded up to three decimals. It should be noted that in the analysis process, sampled series were given individual codes to be able to identify variables during the analysis (model specification or Appendix 1).

4.1. Unit Root Tests

According to Westerlund and Breitung (2013), a standard econometric empirical research requires testing the stationarity of data. A unit root test was conducted for all independent and dependent variables separately to determine their stationarity. The focus unit root test in this paper was the PP and the Augmented Dickey-Fuller (ADF) tests. ADF (1981) modelled a protocol for testing stationarity by utilising logarithmic series at the 1st difference, denoted as:

$(Ly_t)=\log(y_t)$ (Formula 3)

The following hypotheses are assumed for the ADF unit root test:

H_1: L_y is non stationary against the.

Bento (2011. p. 3) says the ADF has the potential to overcome the problem of autocorrelation frequently found in time series modelling. ADF was estimated at no intercept or trend. However, the ADF has encountered some insignificant criticisms. The PP was also utilised to establish reliability that, data are stationary.

Table 1: Regression tests

Test categories	Test type
Unit root test	Phillip Peron
	Augmented ducker fuller
Estimations	OLS estimation
	Residual test for co-integration
	ECT
	Causality
Diagnostic tests	Serial correlation
	Normality
	Heteroscedasticity
	Stability test

ECT: Error correction term

Phillips and Peron (1988) modelled a nonparametric approach to testing unit root for a wide range of data. This test uses fitted drift and time trend to determine between unit root stationarity and non-stationary in a model. The PP is conduct based on the following model:

Let $\{y_t\}$ be a time series generated by:

$$y_t=\alpha y_{t-1}+u_t \ (t=1,2\ldots.) \qquad \text{(Formula 4)}$$

$\alpha=1$

Castro et al. (2013. p. 3) says the PP and the ADF differ as the ADF perform stationarity on residuals free of serial correlation. Alternatively to the ADF, the PP is utilised on models with weakly dependent errors. It was important to establish if the tested data series were stationary or non-stationary. It was important to utilise stationary data in the estimation of models to avoid spurious regressions. Spurious regressions lead to spurious results that are misleading in terms of inferences drawn. Results from unit root test are presented in Table 2.

Both the ADF and PP tests were conducted on each series. All conduct unit root test produced a stationary outcome at the 1st difference. The p-values from all series were below 0.05. The P-value results in the various unit root tests for all series confirmed positive at a 1% level of significance. Thus, the null hypothesis that data are autoregressive (non-stationary) for each series against the alternative that each series is stationary was accepted.

4.2. OLS Estimation

The OLS estimation test is a test for co-integration in the OLS model. The independent variables CP, coal volume (CV), electricity consumption intensity (ECI) and electricity consumption price (EPR) were tested over the dependent variable electricity production volumes (EPV) to establish if the independent variables can influence the dependent variable. Bento (2011. p. 3) points out that stationarity of data is the only requirement to implement an OLS regression method (Table 3).

The outcome from regression reflects that a significant relationship exists between all the independent variables with the dependent variable. The results reflect that the hypotheses and model specification used in the investigation of the problem of the empirical research is reliable. Outcomes from all independent variables produced a $P < 0.05$, with all series reflecting a positive outcome at a 1% level of significance. The regression analysis further confirmed reliability by obtaining a 97% R^2. The results from the price of electricity reflect similarly to outcomes of Blignaut et al. (2014) and Inglesi (2011). The outcome from price was significant, confirming that price elasticity of electricity in South is becoming increasingly lower through the years and can consequently affect future electricity potential as consumers become very alert to the pricing of electricity.

4.3. Co-integration

On this paper, co-integration was performed through the Engle Granger OLS non-stationarity tests. Ssekuma (2011. p. 3) views that, it is faulty for econometric to accept differencing of OLS series during unit root. It causes a material influence by reducing non-stationary series to stationary as opposed to if tested at levels. Robert et al. (1987) point out that stationarity is precise when no deterministic component is attached to perform stationarity on a data series. Engle and Granger proposed a method which involved performing the ADF test from OLS estimation residuals.

Testing for co-integration on this Engle-Granger approach involved performing the ADF tests on OLS estimation residuals at levels, with the MacKinnon critical values adjusted on variables to determined stationarity. The co-integration approach evaluates if is stationary. If stationarity exists, the OLS estimator is said to be co-integrated. This approach for co-integration assumed the following expression:

$$\hat{u}t = yt - \hat{\delta}o - \hat{\delta}1xt \qquad \text{(Formula 5)}$$

ADF estimation obtains a $P = 0.0002$ and a t-statistic of -4.907166. Results reflect that the independent variable and the dependent variable are highly co-integrated. This implies that there is long-term relationship between the dependent and the independent variables (Table 4).

4.4. Engle Granger "Error Correction Term" (ECT)

Robert et al. (1987) point out that if two variables y and x are co-integrated, the ECT should be defined between the co-integrating variables. Co-integration and ECM verify if a long-run and short-run relationship exist between variables respectively. An elementary ECT model is as follows:

$$\Delta y_t=\chi_0+\chi_1\Delta\chi_1-\tau(u_{t-1})+\varepsilon_t \qquad \text{(Formula 6)}$$

The generated residual series derived from the the simple OLS co-integration estimation are lagged to act as the ECT. The ECT, which is a symbol as u_{t-1}, is expressed as $(y_{t-1}-x_{t-1})$. The ECT is only statistically significant when the coefficient is a negative and the $P < 0.05$. The ECT measures reverse rate of adjustment to equilibrium following an exogenous shock (Table 5).

Table 2: Unit root test

Variables	ADF P-values	PP P-values	Conclusion
CP	0.0000***	0.0000***	H_0 is rejected
CV	0.0001***	0.0001***	H_0 is rejected
ECI	0.0283**	0.0001***	H_0 is rejected
EPV	0.0062***	0.0001***	H_0 is rejected
EPR	0.0000***	0.0000***	H_0 is rejected

CP: Coal price, CV: Coal volume, ECI: Electricity consumption intensity, EPR: Electricity consumption price, EPV: Electricity production volumes

Table 3: OLS estimations

Variables	t-statistics	P-value	Conclusion
CP	19.67969	0.0000***	H_0 is rejected
CV	3.001454	0.0042***	H_0 is rejected
ECI	2.086586	0.0419*	H_0 is rejected
EPR	−2.278119	0.0269*	H_0 is rejected

OLS: Ordinary least square, CP: Coal price, CV: Coal volume, ECI: Electricity consumption intensity, EPR: Electricity consumption price, EPV: Electricity production volumes

Error correction was estimated to present short-term dynamics that exist between influencing factors and the grid. Results from the ECT regressor reflect that the model is balanced. The ECT coefficient was found to be negative (−0.442332) and statistically significant with a P = 0.0009. The result reflects that the speed of adjustment on any shock by the dependent variables on the independent variables will be approximately 44%. This indicates that over 44% of the disequilibrium in the previous quarter is adjusted to their long-run equilibrium in the current quarter.

After the OLS estimation, a uni-lateral causality test was conducted to establish if the independent variables granger causes the dependent variables. H_0 (null hypothesis) assumed that the independent variables do not granger cause or impact the dependent variable. Regression outcome from ECI, CV, CP and EPR rejected with the aforementioned variables producing $P < 0.05$. Thus, independent variables, ECI, CV, CP, EPR, test significance to have an impact on EPV (Table 6).

4.5. Diagnostic Test

Dalla et al. (2015. p. 1) state that it is customary to perform a diagnostic assessment to properties from data used for empirical research in time series modelling. Brooks (2009. p. 43) brings to light that the diagnostic tests seek to assess the degree of fairness from regression outcomes. These tests require $P > 0.05$ to be considered significant.

4.5.1. Normality test

The Jarque-Bera (J-B) test was used in testing for normality. According to Brooks (2008. p. 57) the J-B estimate normality through the skewness and Kurtosis statistics. The J-B assumes that the null hypothesis is normally distributed against the alternative hypothesis that other distributions are present. Referring to Cameron (2005. p. 238), the J-B test combines the skewness and the kurtosis according to the following formula:

$$\text{J-B}=n[(S^2/6)+\{(K-\frac{3)^2}{24}\}] \quad \text{(Formula 7)}$$

The generated residual series derived from the the simple OLS

Cameron elaborated on the equation, is the sample size, the skewness and the kurtosis. If skewness slopes to the right or the left, then the distribution is not normally distributed. Kurtosis measures how steeply values are rising to the most likely value in the distribution curve. According to Gujarati (2004. p. 148) under the J-B test, if the computed p-value is sufficiently low, the alternative hypothesis should be accepted that residuals are not normally distributed. Alternatively, if p-values are reasonably high, the normality assumption is not rejected.

Table 4: Engle-Granger OLS co-integration test

Description	t-Statistic	P value	Conclusion
ADF test statistic	−4.907166	0.0002***	H_0 is rejected
Test critical values			
1% levels	−3.555023		
5% levels	−2.915522		
10% levels	−2.595565		

OLS: Ordinary least square

Table 5: ECT results

Coefficient	t-statistics	P value
−0.442332	3.523117	0.0009***

ECT: Error correction term

4.5.2. Serial correlation

The Serial correlation test provides evidence if error term values within sampled periods are systematically dependent (Studenmund, 2011. p. 304). Baltagi (2008. p. 92) warns that is biased in ignoring serial correlation if detected in analysed data. Regression will provide required but unethical estimates if serial correlation is detected and ignored. The Correlogram test was used in detecting serial correlation among data series. Referring to Nopiah et al. (2010) the Correlogram test, aim at sensing the presence of serial correlation in a specified order in the autocorrelation tested lags. Gujarati and Porter (2009. p. 434) highlight that the advantage of the Correlogram test is that it detects the presence of higher-order serial correlation.

Hypotheses developed in testing for serial correlation are:

H_0: $\rho = 0$ and H_1: $\rho \neq 0$.

The hypothesis H_0 denotes that no serial correlation exists while the alternative, H_0, on the other hand assumed that there was serial correlation. Data were tested for serial correlation because in general, econometrics established the OLS is commonly inconsistent in the presence of lagged dependent variables and serially correlated errors. Even though Wooldridge (2006. p. 415) holds that most of such assumptions are false, it was necessary to test for serial correlation to prove the precision of coefficient estimates.

4.5.3. Heteroscedasticity

Wooldridge (2009. p. 278) states that the test for heteroscedasticity investigates whether or not heterogeneity exists among estimates. Baltagi (2005. p. 99) elaborates that the test assumes that disturbances from regressions are homoscedastic with the same variance across time and individuals.

In this paper, the White's cross section and the Arch tests were used. Studenmund (2011. p. 350) says the White test detects the heteroscedasticity by considering the squared residuals as the dependent variable when performing regression. The following hypotheses were developed:

$H_0: \sigma_t^2 = \sigma$ (The null hypothesis assuming homoscedastic errors) and

H_1: Not equal for all t, (the alternative hypothesis assuming heteroscedastic errors).

In agreement with Asteriou and Hall (2011. p. 127), the White's cross-section test was employed in this study because it does not assume any determination of heteroscedasticity.

All series acquired a P > 0.05 for the normality, serial correlation and heteroscedasticity tests respectively. Thus, diagnostic results acquired a positive significance for tested series (Table 7).

4.5.4. Stability test

Brown et al. (1975), developed the recursive stability test for OLS models under the following parameter:

$$y_t=x_t b_t+u_t \quad \text{(Formula 8)}$$

Where, y_t, is the observation on the dependent variable, x_t, is a K × 1 column vector of non-stochastic repressors,b_t is a K × 1 vector of regression coefficients,, is a disturbance term, with mean zero and variance σ_t^2.

Farhani (2012) alludes that the recursive value also estimates the level of stability significance at a 5% critical line benchmark. The test is referred to as the cumulative sum (CUSUM) of squares test, and it uses the sum of squared recursive residuals, as reflected by an estimation graph. It tests the null hypothesis under the assumption that the dependent variable "s_m" follows a Beta distribution with a mean, equals to independent parameters, E (Sm) = [(m-K)/(T-K)].

The OLS recursive stability test assumes a negative result if the constructed forecasting model is stable over the sample period and remain stable over the forecast period. If the model's parameters are different during the forecast period than the sample period, the model estimation will be viewed as irrelevant regardless of how perfectly it was estimated.

Figure 1 reflects the recursive residual test. It is evident that none of the model's parameters changed at one or more points in the sample period. Results reflect that the regression model is stable over time because as t increases the recursive parameter estimates stabilise at level. A conclusion can be made that the stability of CP, CV, EPR and ECI is of crucial importance for consistent electricity supply.

Figure 2 reflects the significance level of the CUSUM estimation. The CUSUM test falls within the accepted critical value of 5%. Results reflect that the model parameters are stable over the tested time periods.

5. CONCLUSION AND POLICY IMPLICATIONS

The empirical research of this paper was assessing the sustainability of the electricity grid in meeting the pressure of current and future demand. Von Keltehodt and Wocke (2008) note that if electricity demands exceed supply, the unreliability of electricity supply increases.

This paper has provided reliable evidence of the significant threats to the electricity security in South Africa. The Engle-Granger co-integration test concurs that both the short and long-term relationship between the dependent variable and the independent variables. Stability tests confirm that the tested independent variables, electricity price, CP, CV and increase in grid consumption have a consistent pattern to the dependent variable. Causality test also confirms that the independent variables can cause an impact on the dependent variable. This has a direct consequence on electricity supply in general because as production falls, supply is adversely affected in high proportions. Hameed and Khan (2016) assert that an electricity grid is under siege if production potentials are not comparative to the constantly increasing demands of the industrial and domestic sectors. Thus, Clark et al. (2005. p. 29) concur the security of electricity is threatened if the physical quantity of available electricity is insufficient for consumers. Considering that South Africa is an energy-intensive economy, developing sustainable electrical energy frameworks should be a major element for strategic policymakers.

The raison d'être behind this article was to encourage research on electricity security and to recommend applicable policy guidelines in attaining a secure electricity environment in South Africa. It is acknowledged that initiative programmes have been established to ensure the security of electricity supply in South Africa. However, initiatives are still to be effectively prioritised and applied. Policy makers are still to develop reliable and applicable dynamic parameters towards electricity security in South Africa. Current efforts show that the focus has been on coal generation, which has proven to be unsustainable. South Africa should explore new sustainable and energy efficient technology generation sources such as renewable

Table 6: Causality test

Null hypothesis	F-statistic	P-value	Conclusion
ECI does not granger cause EPV	3.08677	0.0524*	H_0 is rejected
CV does not granger cause EPV	4.11640	0.0207**	H_0 is rejected
CP does not granger cause EPV	1.83146	0.0583*	H_0 is rejected
EPR does not granger cause EPV	10.1456	0.0002***	H_0 is rejected

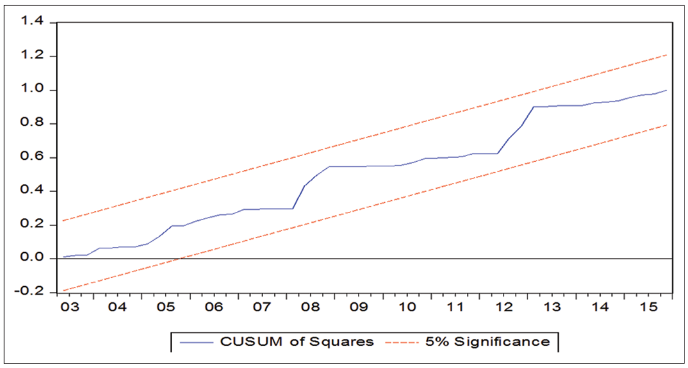
CP: Coal price, CV: Coal volume, ECI: Electricity consumption intensity, EPR: Electricity consumption price, EPV: Electricity production volumes

Table 7: Diagnostic tests results

Test	Measurement	Hypothesis	P-values	Conclusion
Normality	Jarque-Bera	H_0: All t is normally distributed H_1 not all t is normally distributed	0.8382	Errors were normally distributed
Serial correlation	Correlogram test at (1st difference)	H_1: ρ=0 H_1: $\rho\neq$0	0.15	Serial correlation was not detected
Heteroscedasticity	White's test Arch test	$H_0 : \sigma_t^2 = \sigma$ H_0: Not equal for all t	0.0690 0.1330	The white and arch test reflects that series are homoscedastic

Figure 1: Recursive residual test

Figure 2: The cumulative sum estimation test



energies with more security potentials compared to other sources. Electricity security can be attributed to the capability of an electricity grid in meeting up the electricity needs of final consumers (Raillon, 2010. p. 2). Energy security will turn around the negative social and economic development in South Africa. Energy strategies should consider renewable energy as the most effective option for future South Africa electricity needs and energy systems advancement.

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