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Electricity consumption, trade openness and economic growth in South Africa: An ARDL approach

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Holistic economic system which involves production, distribution and consumption of goods and services depends on energy; implying that the growth of most developing and emerging economies is directly or indirectly tied to energy access and its consumption. Thus, energy plays a crucial role in the production of goods and services consumed locally or exported abroad through international trade. Energy production and trade openness are therefore among the essential variables of a country's economic wellbeing. This study examines the short- and long-run relationships as well as the causal directions between electricity consumption, trade openness and economic growth in South Africa from 1984 to 2015 using autoregressive distributed lag (ARDL) model. This study found that both the electricity consumption and trade openness have a positive and significant effect on economic growth in the long-run. Granger-causality test revealed that electricity consumption and trade openness Granger-cause economic growth without any feedback effects. This concluded that South Africa's economy significantly benefits from boosting energy production and trade openness.

Keywords: ARDL, economic growth, energy consumption, trade openness, South Africa

1. Introduction

The role that electricity continues to play in meeting the socioeconomic needs of the increasing population and in boosting the economic growth of sub-Saharan Africa cannot be over- emphasized. Energy generally, and electricity specifically has become the bloodline of most economies as it

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drives every sector of the economy (Mensah, 2014). The overall economic system which involves production, distribution and consumption of goods and services depends on energy. This implies that the growth of most developing and emerging economies is directly or indirectly tied to energy access and its consumption. There has been a growing debate on the impacts of different sources of electricity generation in various countries in the recent time (Zaidi et al., 2016; Akinwale et al., 2015; Akinwale et al., 2013). This is as a result of the environmental challenges facing the globe ranging from carbon emission, flood risk, and melting glacier among others (Akinwale et al., 2014). This has posed a serious argument, which resulted into the suggestion of energy conservation policy, for many countries especially those wasting energy and those using unfriendly means to generate electricity (Zerbo, 2016; Dorgan, 2016). While some studies such as Soytas and Saris (2003) as well as Lean and Smyth (2010) suggested conservation policy in an economy where energy consumption reduction will not affect economic growth, others such as Akinlo (2009) and Narayan and Smyth (2009) believed that such policy will have negative effect on the economic growth which may reduce the pace of industrialisation of such country. This line of studies remain inconclusive as many developing countries especially in Africa and Asia still depend largely on fossil fuel and coal to generate energy and electricity. Energy is utilised in the production of goods/services which are finally consumed locally or exported abroad through international trade. International trade and trade openness involves the movement of goods and services produced from one country to another for consumption or further production (Sadorsky, 2011). Production of those goods would have been difficult or impossible without the effective use of energy (Shahbaz et al., 2014). Trade openness is expected to stimulate domestic production which hitherto engenders economic growth. It also facilitates developing economies to import advance technologies from developed economies. Thus, energy consumption, economic production and international trades tend to move together which makes it interesting to examine the relationship between them in an economy (Nasreen and Anwar, 2014).

Despite that South Africa accounted for the largest proportion of electricity generation and consumption in sub-Saharan Africa (Central Intelligence Agency, 2014), the country still faces various social and economic challenges. Government-owned power company 'Eskom' produced over 90 per cent of the country's electricity, while coal-fired

plant contributes an average of 92 per cent to electricity generation making it the main source of electricity generation in the country's energy mix (StatSA, 2015). The electricity consumption per capita in South Africa was 4,841 kwh in 2015 while that of Egypt was 1,697 kwh and that of Nigeria was 142 kwh (World Band Development Indicators, 2016). This clearly shows that an average South African enjoys electricity access than other countries in Africa.

South Africa is an upper middle-income country and the second largest African economy behind Nigeria with a gross national income per capita of US$ 7,575 in 2015 using GDP per capita at 2010 constant US$ (WDI, 2016). South Africa is part of the South African Customs Union (SACU) which comprises Botswana, Lesotho, Namibia and Swaziland (Kumar et al., 2015). The population size stands at about 55 million, while the services sector accounts for an average of 68 per cent of South Africa's GDP, the manufacturing and mining sector accounts for approximately 22 per cent and agriculture an average 3 per cent (WDI, 2016). The South African total export trade declined from $91 billion in 2014 to $81.6 billion in 2015 and the total import trade also declined from $122 billion in 2014 to $104.6 billion in 2015. The GDP per capita (at constant 2010 US$) also fell from $7,603 in 2014 to $7,575 in 2015. South Africa like many countries in the world faced a declined economic growth in 2015 but remains the second largest economy in Africa. Looking at the potentials of South African economy, based on the electricity usage, level of import and export among others, there is need to investigate some variables and proffer means to improve the growth and productivity in the country.

Albeit, there are numerous studies on the relationship between electricity consumption and economic growth as well as the relationship between trade openness and economic growth, but there is a dearth of study on the relationship between trade openness and electricity consumption as well as on the joint relationship between electricity consumption, trade openness and economic growth in a single model. Sardosky (2012) argued that understanding the relationship between energy consumption, trade and output is important to understanding current energy and environmental policy, and developing new effective energy and environmental policy. As the population of the country is growing rapidly and economic growth is seen as imminent, there is need to investigate the long run relationship as well as the causal direction between trade

openness, electricity consumption and economic growth in South Africa so as to provide policy suggestions that could assist the government in channelling its efforts towards the right direction. While few studies (Sardosky, 2012; Siddique and Majeed, 2015) available on the three variables are mainly panel data which might not capture the country-specificity very well, other studies (Soytas and Sari, 2003; Nasreen and Anwar 2014) focus mainly on countries in Asia, America and Europe. Thus, a South African study combining electricity consumption, trade openness and economic growth in a single model would shed more light on the topic in the African context.

2. Literature review

This section reviews the relationship between electricity consumption, trade openness and economic growth in different countries. Some of the studies focus on electricity consumption and economic growth, trade openness and economic growth, electricity consumption and trade openness and the three variables together. The direction of causality of each of these variables has an important implication towards a country's government policy. In the case of electricity consumption and economic growth, if the causality runs from electricity consumption to economic growth, it depicts a growth hypothesis because electricity consumption is vital to economic growth; while the reverse depicts the conservation hypothesis where reduction in electricity consumption will not affect economic growth (Payne, 2010). For trade openness and economic growth, the causality from former to later means export-led growth hypothesis; while the reverse is the trade restriction hypothesis. Finally, the causality from trade openness to electricity consumption indicates that implementing energy conservation policy will not affect export and import trade; whereas the unidirectional causality from electricity consumption to trade openness shows that electricity conservation policy will impair the nation's international trade (Sardosky, 2012).

Dorgan (2016) analysed the short run and long run relationship between energy consumption (renewable and non-renewable) and economic growth in Turkey, and found that renewable energy consumption has an insignificant impact on economic growth, while non-renewable energy consumption has a significant positive effect on it. However, energy consumption (both renewable and non-renewable) has a feedback effect on economic growth in Turkey. Studies such as Zaidi et al. (2016) in sub-

Saharan Africa; Yang (2000) in Taiwan; Gurgul and Lach (2012) in Poland; Yoo (2005) in Korea; and Odhiambo (2009) in South Africa among others found a feedback effects between electricity consumption and economic growth in various countries and regions. Unidirectional causality was found from economic growth to electricity consumption in some studies such as Lean and Smyth (2010) in Malaysia; Akinwale et al. (2013) in Nigeria and Soytas and Sari (2003) in Italy and Korea. While unidirectional causality from electricity consumption to growth was also found in studies like Soytas and Sari (2003) also found in France, Germany, Japan and Turkey; Acaravci et al. (2015) in Turkey; and Akinlo (2009) in Nigeria, no causality was found by Huang et al. (2008) in low-income countries; and Ozturk and Acaravci (2013) in Turkey. There are also mixed result on the relationship and direction of causality between electricity/energy consumption and trade openness. While there was no causality between energy consumption and trade openness in the study of Lean and Smyth (2010) in Malaysia; unidirectional causality was found by Sultan (2011) and Sbia et al. (2014) in Mauritius and Bahrain respectively; and bidirectional causality was found by Shahbaz et al. (2013a) and Kyophilavong et al. (2015) in Indonesia and Thailand respectively. The studies on openness and economic growth also found differing results (Giles and Williams, 2000; Saibu 2004; Al-Mawali, 2004; Awokuse, 2008; Burange et al., 2013; Ulasan, 2015; Hye and Lau, 2015; Sakyi et al., 2015).

The studies which investigate the relationship and direction between electricity consumption, economic growth and international trade together in a model are very few and quite recent. The study by Lean and Smyth (2014) was among the few studies that examined the relationships between these variables using an augmented production framework between 1980 and 2013. The results showed that a 1 per cent increase in electricity consumption generates 0.03 per cent to 0.05 per cent increase in output; a 1 per cent increase in total trade results in 0.5 per cent increase in output; and a 1 per cent increase in trade openness results in 1 per cent increase in total output. Lean and Smyth (2014) found that electricity consumption Granger causes GDP in Bhutan; however, all other variables were found to be independent. Thus, their study suggested that Bhutan is energy dependent and it could only promote economic growth through further investment in electricity generation. Shakeel et al. (2014) investigated the relationship between energy consumption, trade and economic growth in five South Asian countries using a panel framework.

Their main results were that the three variables have feedback effects on one another in the short run, while in the long run there was bidirectional Granger causality only between energy and economic growth and unidirectional Granger causality running from exports to energy, and from exports to GDP. Nasreen and Anwar (2014) explored the causal relationship between economic growth, trade openness and energy consumption using panel cointegration regression and causality approaches for the period of 1980–2011 in 15 Asian countries. Their empirical results confirmed the presence of cointegration between variables and also revealed the bidirectional causality between economic growth and energy consumption, trade openness and energy consumption. Also, Siddique and Majeed (2015) using the data from 1980 to 2010 examine the relationship between trade, energy consumption, financial development and economic growth with panel co-integration approach in five South Asian countries. They found that there is a long run relationship among the variables and the variables positively affect the economic growth. Furthermore, they found that bidirectional relationship only exists between growth and energy, and between trade and financial development in the long run.

Sadorsky (2011) in eight Middle Eastern countries found a bidirectional causality between imports and energy consumption and a unidirectional causality from exports to energy consumption. The results indicated that increasing trade trend positively affects the demand for energy. In another study by Sardosky (2012), a panel cointegration technique was used to examine the relationship between energy consumption, output and trade in seven South American countries covering the period 1980 to 2007. The results of the short-run dynamics showed a bi-directional feedback relationship between energy consumption and exports, output and exports and output and imports but there is evidence of a one way short-run relationship from energy consumption to imports. In the long-run on the other hand, there is evidence of a causal relationship between trade (exports or imports) and energy consumption. Narayan and Smyth (2009) using a panel of six Middle Eastern countries (Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria) found short-run Granger causality running from electricity consumption to real GDP and from income to exports. They also found evidence of a long-run Granger causality relationship running from exports and electricity consumption to real income and from exports and real income to electricity consumption. Also, Shahbaz et al. (2013b) investigated the relationship between energy consumption and economic

growth by incorporating financial development, international trade and capital as important factors of production function in case of China over the period of 1971–2011 using the Auto-regressive distributed lag (ARDL). All the variables were found to have positive impact on economic growth, and there was a unidirectional causal relationship running from energy consumption to economic growth, and bidirectional causality between international trade and energy consumption, between financial development and international trade, between capital and energy demand, and between international trade and economic growth. Furthermore, Acaravci et al. (2015) examined both the long run and causal relationships between electricity consumption per capita, real GDP per capita, trade openness and foreign direct investment inflows per capita in Turkey during the time period 1974-2013. The results revealed the evidence of long run relationship between the variables, and strong causalities running from the electricity consumption per capita, trade openness, and FDIs per capita to real GDP per capita. Kumar et al. (2015) explored the role of energy, trade and financial development on economic growth using ARDL with data of 1971-2011 in South Africa. Granger causality results show that a unidirectional causality from capital stock and energy consumption to output; and from capital stock to trade openness; a bidirectional causality between trade openness and output; and absence (neutrality) of any causality between trade openness and energy and between financial development and output.

It could be seen from the literature that there are diverse results from the past studies and these could be traced to country-specific peculiarities, index used to proxy variables and methodological differences. Some earlier literature may suffer from the problem of omitting important variables while using only two variables in the model and many of the studies in sub-Saharan Africa are mainly panel data which may not be able to critically examine the specificity within a country. There are some studies that use either only export or import to proxy trade openness and a particular study by Kumar et al. (2015) in South Africa which used energy consumption per capita to proxy energy consumption, and imports plus exports as percentage of GDP to proxy trade openness. Our study uses electricity consumption per capita to proxy electricity consumption, and the additions of import and export as a ratio of the country's population to obtain trade openness so as to ensure that all the variables are on the same base of per capita, and this is seen as an improvement to the earlier work in this regard.

3. Methodology

3.1 Data and sample period

Annual time series data covering the period 1980–2015 on electricity consumption per capita (in Kwh), GDP per capita (Constant at 2010 US$) and trade openness (export plus import as a ratio of population) were collected from the 2016 update of World Bank's World Development Indicator (WDI) as published through the online database of World Bank. The variables used in the models are: GDP for real GDP per capita; ELE for total electricity consumption per capita; and TOPN for trade openness per capita. The sample period was selected based on the availability of data.

3.2 Model specification

This study adopted the autoregressive distributed lag (ARDL) model by Pesaran et al. (2001) to test the relationship between electricity consumption, trade openness and economic growth. This model was selected because it can accommodate a mixture of variables that are stationary at level, I(0) and those that are stationary at first difference, I(1). The ARDL model can therefore be used when variables are I(0), I(1), or a mixture of I(0) and I(1), but it cannot be used when variables are stationary at the second difference, I(2) (Pesaran and Shin, 1998). Before conducting formal tests, descriptive statistics and correlation analysis were used to conduct a preliminary analysis of trend and variability of the variables. In addition to the ARDL, Granger's (1969) causality test was employed to establish the causal relationships between electricity consumption, trade openness and economic growth. The ARDL model used to test for the short and long run relationships between the variables is expressed as follows:

$$\Delta LGDP_t = \alpha_0 + \sum_{j=0}^{n} \beta_j \, \Delta LGDP_{t-j} + \sum_{j=0}^{n} \gamma_j \, \Delta LELE_{t-j} + \sum_{j=0}^{n} \delta_j \, \Delta LTOPN_{t-j} + \varphi_1 LGDP_{t-1} + \varphi_2 LELE_{t-1} + \varphi_3 LTOPN_{t-1} + u_t \quad (1)$$

Where: $\Delta LGDP_t$ represents the change in the natural log value of GDP at time t; $\Delta LELE_t$ is the change in the natural log value of electricity consumption at time t and $\Delta LTOPN_t$ is the change in the natural log value of trade openness. α_0 is the intercept, n is number of lags and u_t is the error term. Coefficients β_j, γ_j and δ_j represent the short-run dynamics of

the model; while φ_1, φ_2, and φ_3 are used to test for the long-run relationship known as bound cointegration test. Based on Equation 1, the following hypothesis was therefore set to test for co-integration:

Null hypothesis (H_0) for no co-integration: $\varphi_1 = \varphi_2 = 0$
Alternative hypothesis (H_1) for co-integration $\varphi_1 \neq 0$, $\varphi_2 \neq 0$

To test this joint hypothesis, bound cointegration tests were used where the estimated F-statistic was compared to the critical values from the Pesaran *et al.* (2001) table with unrestricted intercept and no trend. This table has lower and upper critical values and if the estimated F-value is greater than the upper critical value, the H_0 is rejected in favour of H_1. This would imply that there is a cointegrating relationship between the variables. However, if the lower critical value is greater than the estimated F-value, the H_0 cannot be rejected and this implies that there is no cointegration between the variables. Lastly, unless there is additional information, the result remained inconclusive if the calculated F-statistics lay between the upper and lower critical values. The existence of cointegration provides evidence for a long-run relationship between the variables and it means that an error correction model (ECM) has to be estimated to capture the adjustment to the equilibrium (Muzindutsi and Sekhampu, 2013). The ECM equation derived from the ARDL model in Equation (1) is as follows:

$$\Delta LGDP_t = \alpha_0 + \sum_{j=0}^{n} \beta_j \, \Delta LGDP_{t-j} + \sum_{j=0}^{n} \gamma_j \, \Delta LEL_{t-j} + \sum_{j=0}^{n} \delta_j \, \Delta LTOPN_{t-j} + \lambda u_{t-1} + e_t \quad (2)$$

Where u_{t-1} is the error correction term (ECT) and λ is the ECT coefficient which measures the speed of adjustment to the equilibrium. The ARDL was estimated using EViews 9 and the best ARDL model was selected based on the comparison of Akaike Information Criterion (AIC) and the Schwarz's Bayesian information criterion (SBIC). Various diagnostic tests such as serial correlation, heteroscedasticity, structural breaks and normality tests were conducted to check if the selected ADL model met the required econometric assumptions.

4. Results and discussion

4.1 Descriptive and correlations analysis

Table 1 summarise the descriptive information for the three variables. The mean of the natural log seem to be in the same range and standard deviations appeared to be small indicating low variability around the means. However, trade openness has a higher standard deviation than electricity consumption and economic growth, suggesting that it has been more volatile than the other two variables. This is expected as the trade openness is normally affected by both external and internal factors (Saibu, 2004; Shahbaz et al., 2013b). The skewness for all three variables seems to be close to zero, suggesting a normal distribution. The normal distribution is also confirmed by Jarque-Bera test (p-values > 0.05), which shows that the three variables are normally distributed.

Table 1: Descriptive statistics

	LELE	**LGDP**	**LTOPN**
Mean	8.399263	8.798986	7.467065
Median	8.396130	8.783138	7.260551
Maximum	8.529359	8.937158	8.417292
Minimum	8.200958	8.671902	6.769473
Std. Dev.	0.070829	0.089576	0.500322
Skewness	-0.772778	0.217023	0.700966
Kurtosis	3.694325	1.652433	2.000578
Jarque-Bera	4.306242	3.006497	4.446389
Probability	0.116121	0.222407	0.108263
Observations	36	36	36

Correlation results in Table 2 show that all coefficients are positive, suggesting a positive association between the variables. However, the p-value for LELE and LTOPN is greater than 0.05, implying that the correlation between electricity consumption and economic growth is not statistically significant at 0.05 significant level. The significant positive association is therefore observed between electricity consumption and trade openness, and between economic growth and trade openness. This is in line with the literature and other studies (Lean and Smyth, 2014; Kyophilavong et al., 2015) which found a positive association between trade openness, electricity consumption and economic growth. Since the

existence of significant correlation does not imply causality, it is important to conduct more econometric tests to establish the short- and long-run relationships between the variables.

Table 2: Correlation coefficients and p-values

	LELE	**LGDP**	**LTOPN**
LELE	1.000000		

LGDP	0.059158	1.000000	
	(0.7318)	-----	
LTOPN	0.408890	0.802310	1.000000
	(0.0133)	(0.0000)	-----

p-values in brackets

4.2 Results of unit root tests

Given that the ARDL model can produce unreliable results when variables are stationary at the second difference I(2); the unit root test was conducted, to ensure that none of the variables is I(2). The unit root testing of the variables was based on the Augmented Dickey-Fuller (ADF) test by Dickey & Fuller (1981) and complemented by Phillips-Perron (PP) test by Phillips-Perron (1988). Unit root test results, in Table 3, showed that electricity consumption is I(0), while trade openness and economic growth are I(1). Thus, there is a mixture of I(0) and I(1) but none of the variables is I(2), suggesting that ARDL is the appropriate model to test for cointegration.

Table 3: Results of unit root tests

Variable	**Model**	**ADF**		**PP**		**Order of integration**
		Levels	First Difference	Levels	First Difference	
LELE	Constant Trend	-3.002** -3.430*	-- --	-3.006** -3.422*	---- -----	I(0)
LTOPEN	Constant Trend	-0.8618 -2.2836	-4.0593*** -4.9267***	-0.4927 -2.6953	-4.5432*** -4.6198***	I(1)
LNGDP	Constant Trend	-0.2711 -2.6914	-4.5876*** -4.6204***	-0.5703 -1.3507	-4.1943*** -4.9267***	I(1)

(***), (**), (*) indicate 1%, 5% and 10% level of significance, respectively

4.3 Analysis of the long-run relationship

The best ARDL model was estimated and the comparison of AIC and SBIC information criteria showed that ARDL (2, 1, 1) is the best model to estimate short- and long-run relationships between the variables. Results of bounds cointegration test are shown in Table 4. These results showed that the estimated F-value is greater than the upper critical values at 0.01 significant level. Thus, the null hypothesis for no-cointegration is rejected in favour of the alternative hypothesis for cointegration. This implies that there exists a long-run relationship between electricity consumption, trade openness and economic growth. The estimated of this long-run relationship are summarised by Equation 3 below.

Table 4: ARDL Bounds Test

Test Statistic	**Value**	**K**
F-statistic	5.900312	2
Critical Value Bounds		
Significance	**I0 Bound**	**I1 Bound**
10%	2.17	3.19
5%	2.72	3.83
2.5%	3.22	4.5
1%	3.88	5.3

$$LGDP = 1.7763 + 0.8506\ LELE + 0.2175\ LTOPN \quad (3)$$

Equation 3 shows that both LELE and LTOPN have positive long-run effects (significant at 0.05 significance level) on LGDP. The coefficient for LELE indicates that a one per cent increase in electricity consumption increases the economic growth by 0.8506 per cent, holding other factors constant. For LTOPN, a one per cent increase in trade openness is associated with 0.2175 per cent increase in economic growth, holding other factors constant. These results suggest that, in the long-run, South African economy can benefit from increasing the energy production and trade openness. These results are in line with findings from other studies (Nasreen and Anwar, 2014; Zaidi et al., 2016) which found a positive long-run relationship between economic growth and electricity/energy consumption and trade openness. South Africa's economic tends to benefit from increase in trade openness because countries which

experience positive long run relationship between export and economic growth are more open to outside influences and generate externalities, such as the incentive to innovate (Ahmad, 2001);. These efficiency gains increase GDP through increasing total factor productivity (TFP) in the Solow-Swan growth accounting framework (Lean and Smyth, 2014). Thus, these findings suggest that the country's economy can benefit from boosting energy production and this can eventually grow export and allow South Africa to benefit more from trade openness.

4.4 Analysis of the short-run relationships

Table 5 summarizes the ECM results estimated from Equation 2. Before interpreting these results, the diagnostic tests were conducted (results are reported in Section 4.6) and the ECM model passed all the diagnostic tests. The error correction term (u_{t-1}) coefficient has the desired negative sign and is statistically significant at 0.05 significance level because its absolute t-Statistic (4.912) is greater than the upper bound of the critical t-value (3.22) from Pesaran et al. (2001). The coefficient of -0.17681 suggests that approximately 17.68 per cent of any deviation from equilibrium is corrected each year. In other words, any changes in electricity consumption and trade openness take about 5.656 (1/0.1768) years to have the full effect on economic growth. The coefficient for lag of LGDP is significant at 0.1 level of significance, suggesting that a previous change in economic growth has a positive effect on the current economic growth. The coefficients for changes in electricity consumption and trade openness are positive and significant at 0.01 significant level; implying that these two variables have a significant short-run effect on economic growth. These results suggest that changes in energy consumption and trade openness can be used to boost the short-run growth of the South Africa's economy. This is similar to the results of Acaravci et al. (2015) in Turkey and Kumar et al. (2015) in South Africa. Policies to increase the level of electricity consumption and trade liberalisation should be encouraged in the South African economy.

Table 5: ECM results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LGDP(-1))	0.228284	0.121267	1.882492	0.0702
D(LELE)	0.190180	0.065998	2.881602	0.0075
D(LTOPN)	0.082736	0.019482	4.246845	0.0002
u_{t-1}	-0.176810	0.03599	-4.912754	0.0103

4.5 Analysis of causal relationships

Pairwise Granger-causality tests were used to further analyse the short-run relationships between variables. Results in Table 6 shows that there are two significant unidirectional Granger-causality relationships. The Granger-causal relationships from LELE to LDGP and from LTOPN to LDGP are significant at 0.1 and 0.05 significant levels, respectively. This suggests that both electricity consumption and trade openness Granger-cause the economic growth. Thus, electricity consumption and trade openness have a significant effect on current changes in economic growth. However, the economic growth does not Granger-cause electricity consumption and trade openness. This indicates that conservation and restriction policies will hamper the economic growth of South Africa. Government should energise the generation of more electric power to boost the economic activities in the country. Trade liberalisation that is properly monitored by the government officials should also be strengthened as this will boost the level of economic growth and also fosters indigenous capabilities of the South Africans. These Granger-causality results confirm the ECM results that consumption and trade openness have a short-run effect on economic growth.

Table 6: Pairwise Granger Causality Results

Null Hypothesis:	F-Statistic	Prob.	Causality
D(LGDP) does not Granger Cause D(LELE)	0.20623	0.8148	No
D(LELE) does not Granger Cause D(LGDP)	2.93424	0.0691	Yes at 10%
D(LTOPN) does not Granger Cause D(LELE)	0.31503	0.7322	No
D(LELE) does not Granger Cause D(LTOPN)	1.70629	0.1993	No
D(LTOPN) does not Granger Cause D(LGDP)	3.69427	0.0372	Yes at 5%
D(LGDP) does not Granger Cause D(LTOPN)	0.67036	0.5193	No

4.6 Results of diagnostic tests

Residual diagnostic tests and stability tests were conducted to test if the estimated ARDL model met the econometric assumptions. Results in Table 7 show that the model passed all the tests. The null hypotheses for no presence of autocorrelation and heteroscedasticity were not rejected and residuals were found to be normally distributed. Ramsey RESET Test shows that the model is correctly specified and this suggests that the parameters in the model are stable. The stability was also confirmed by the CUSUM graphs as shown in Figure 1 and 2. This evidence of parameter stability; implies that the relationship between the variables was consistent throughout the sample period. This suggests that major changes in the political environment such as the 1994 democracy or the presence of major economic events did not affect the consistency of the estimated relationship. Thus, there is no need for accounting for changes in political and economic conditions.

Table 7: Summary of diagnostic tests results

Test	**Null hypothesis (Ho)**	**P-values**	**Decision**
ARCH	No conditional heteroscedasticity	0.8899 (F) 0.8854 (Chi-Square)	Do not reject H_0
Breusch-Godfrey Serial Correlation LM Test	No serial correlation	0.4281 (F) 0.3093 (Chi-Square)	Do not reject H_0
Jarque-Bera (JB)	There is normality	0.2167	Do not reject H_0
Ramsey RESET Test	The model is correctly specified	0.3517 (F)	Do not reject H_0

Figure 1: CUSUM at 5% level of significance

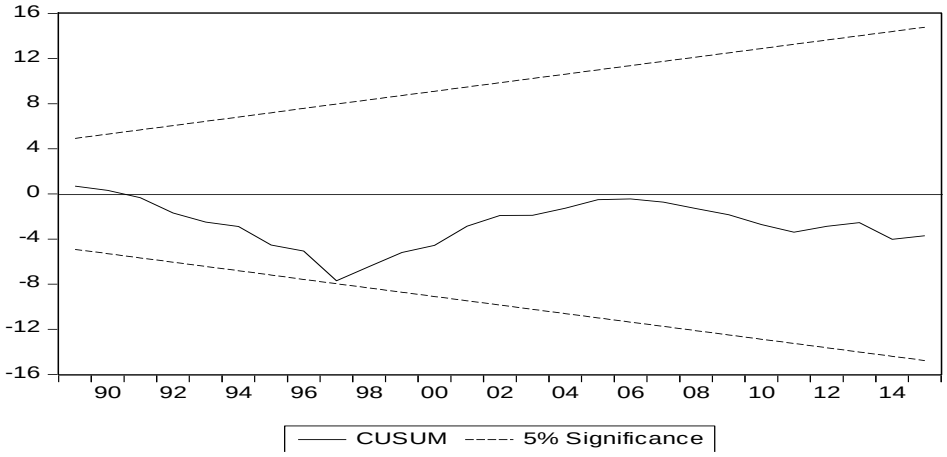
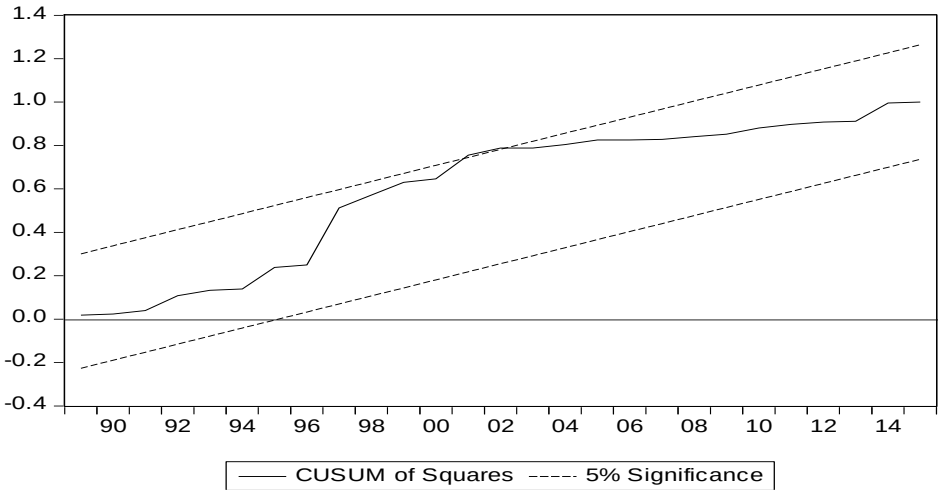


Figure 2: CUSUM of Squares at 5% level of significance



5. Conclusion

This study examined the short run and long run relationships between electricity consumption, trade openness and economic growth. Although more literatures recently show the relationship between electricity consumption and economic growth as well as between trade openness and economic growth, but there is dearth of studies considering the three variables together in a single equation. ARDL approach was adopted for analysis as a result of the advantage it has over other approaches such as combining I(0) and I(1) together. This study found that there is long-run relationship among the three variables as indicated by the co-integration results. Both the electricity consumption and trade have a positive and significant effect on economic growth in the long-run. Granger-causality tests show that electricity consumption and trade openness Granger-cause economic growth without any feedback effects.

Finding of this study showed that South Africa's economy significantly benefits from boosting energy production and trade openness. Thus, the South African government should uphold the policies which encourage the generation and consumption of more electricity in order to boost local production and further create economic growth. Furthermore, the government should also engage in trade liberalisation so as to be able to export some of the goods it has comparative advantage over and the same time import other products especially technologically-related machinery so as to be able to build indigenous innovative capabilities which will boost the country's economic growth.

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