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The Effect of Rural Urban-development Transformation on Electricity Consumption: An Econometric Analysis in South Africa

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ABSTRACT

This paper analyses the impact of urbanization on electricity consumption in South Africa. The sample covers the period from 1971 through to 2013. Trade openness, Capital formation and labour are incorporated as intermittent variables. The Johansen co-integration method and the Granger causality test based on vector error correction model (VECM) are applied to determine this empirical analysis. The results show that the electricity consumption, urbanization, trade openness, labour and capital are co-integrated. It was established that urbanization and trade openness have a positive and a significant impact on electricity consumption. The VECM results reveal an existence of a unidirectional causality flowing from urbanization, trade openness, labour and capital to electricity consumption. The findings of this study bring a fresh perspective for the energy policy makers and urban planners in South Africa.

Keywords: Electricity Consumption, Urbanization, Carbon Dioxide, South Africa
JEL Classifications: C32, O55, Q43

1. INTRODUCTION

South Africa has the largest and most industrialized economy in Africa. Urbanization in South Africa was shaped historically by policies that control the movement and settlement of black people. The aim of these policies was to limit access by Africans to cities but ensure that they settle in the rural areas which mostly had limited economic bases. However, these policies began to break down from the early 1980s. The results from the first census taken post-apertheid showed that 55.1% of the population in South Africa lived in urban areas in 1996 and the number increased to 57.5% in 2001 (Alison et al., 2008). According to StatSA (2011) 64% of the population (which is about 52 million people) live in cities and the number is expected to increase to 70% in 2030.

Urbanization increased at a high rate from the beginning of the 20th century but started to slow down until 1960. This shows that the rapid industrialization which was experienced in the first half of the 20th century attracted more people who were living in the rural areas to relocate to the cities. The preliminary results of the census taken in 1960 showed that the percent of the population living in urban was as follows: Africans (30%), Coloureds (63%), Asians (80%) and Whites (80%) (Alison et al., 2008).

Urbanization growth increased at a slow pace between 1960 and 1990s (Figure 1). This reflects back to the policies which were put in place to limit black people to come stay in the cities. From 1990s through to 2014, urbanization increased at a steady rate. But the increase in urbanization post-apartheid era was not as rapid as would have been expected. Figure 1 shows that urbanization as a percentage of population has been falling steeply from 1994 to the early 2000s. This implies that more population growth was experienced in the rural areas than in the urban areas.

It has been estimated that in the next four decades, the developing countries will become home to 95% of the world's urban population growth (Nations, 2014). The growing concerns about this growth of the population crowded in urban areas include the cost and security of energy supply and the environmental impact of energy production. A larger part of the literature has examined the impact of urbanization on energy consumption and carbon dioxide emissions (Liddle, 2014, Shahbaz et al., 2014, Wang et al., 2016 and Zhang and Lin, 2012). A small body of literature considered both urbanization and trade openness in their studies (Kasman and Duman, 2015; Hossain, 2011).

The studies done on urbanization and energy consumption have mostly focused on the developed countries. Since developing countries are experiencing rapid urbanization, there is a need that more studies focus on these countries. The current study will therefore fill in the gap as it will focus on South Africa, which is one of the developing countries ranked as the 28th largest economy in the world with 62% of its population living in urban areas (Turok, 2012). A common assumption derived from most of the studies done on impact of urbanization on energy consumption is that urbanization and energy consumption have a positive long run relationship (Liddle, 2014, Liu, 2009, Zhang and Lin, 2012, and Rafiq et al., 2016). This assumption may not always be realistic. This leads to this study using the Johansen test of co-integration to examine the relationship between these variables. It further determines the direction of causality among these variables by applying the vector error correction model (VECM) for the period 1971-2013.

The rest of this paper is structured as follows: Section two focuses on the review of empirical literature. Section three presents model specification, data sources and estimation methods. Section four discuses the findings of the study followed by conclusion and recommendations in section five.

2. LITERATURE

Urbanization can be defined as the migration of the people from the agricultural areas to non-agricultural ones. This process results in a larger share of population crowding the urban areas. Physical accumulation of people in urban areas lead to increase in demand for goods and services which include electricity demand. There is an extensive literature investigating the linkage between urbanization and energy consumption undertaken using co-integration techniques and granger-causality approaches. Most of these studies established a long run relationship between urbanization and energy consumption (Lin, 2009; Liddle, 2014; Hossain 2011; Al-Mulali et al., 2015; Kasman and Duman, 2015; Solarin et al., 2016; Shahbaz et al., 2017; Sbia et al., 2017; Gungor and Simon, 2017).

Lin (2009) examined the relationship between energy consumption, population growth, economic growth and urbanisation process. The autoregressive distributed lag (ARDL) model was employed in this study to determine the long run relationship among the variables. Existence of a long run relationship between the variables was discovered. The granger-causality results established that urbanization granger-causes energy consumption both in the long run and short run.

The study by Sodri and Garniwa (2016) purposed to explore the effect of urbanization on road energy consumption and carbon dioxide emissions in megacity Jakarta in Indonesia for the period between 2001 and 2014. The co-integration results proved that there is a long run relationship between the variables. It was also established that urbanization is the main contributer in transport energy consumption. The granger-causality tests validated a unidirectional causality flowing from urbanization to transport energy consumption.

Li and Lin (2015) served to determine the impact of urbanization and industrialization on energy consumption and carbon dioxide emissions using the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework. The data for 73 countries covered a period from 1971 to 2010. The following results were validated: Firstly, in low income countries, urbanization leads to a fall in energy consumption and increases carbon dioxide emission. Secondly, in the middle-/low-income and high income countries urbanization significantly leads to growth in both energy consumption and carbon dioxide emissions. Finally, in the middle-/high-income countries, there is no significant impact of urbanization to energy consumption but it does increases carbon dioxide emissions.

Liddle (2014) used the STIRPAT model to review the impact of population, age structure, household size, urbanization and population density on energy consumption and carbon dioxide emissions. The results posited that urbanization has a positive impact on energy consumption. Zhang and Lin (2012) also employed the STIRPAT model to analyse the impact of urbanization on energy consumption and carbon dioxide emissions at national and regional levels in China covering the period between 1995 and 2010. The results established that urbanization has a positive impact on both energy consumption and carbon dioxide emissions.

Another study that employed the STIRPAT model was conducted by Zhou (2015). This study served to determine the effects of rural-urban development transformation (RUDT) on energy consumption and carbon dioxide emission in China for the period from 1990 to 2012. Their results suggested that the effect of RUDT on energy consumption and carbon dioxide emissions varies across provinces. The RUDT positively affect energy consumption and carbon dioxide emissions in China and its eastern and central regions.

Another Chinese study was done by Yang et al. (2016) to examine the effect of urbanization on renewable energy consumption. The study incorporated energy mix, energy intensity, economic growth, and population as the additional variables. The results posited that energy mix effect, economic effect and population effect positively affect renewable energy consumption growth, while energy intensity negatively affect renewable energy consumption growth. Urbanization was found to have a greater impact on the total energy consumption growth than on renewable energy consumption growth.

Fan et al. (2017) carried a study to investigate the impact of urbanization on residential energy consumption in China. This study considered aggregated and disaggregated residential energy consumption during 1996-2012. The results validated that urbanization contributed 15.4% to increase in aggregated residential energy consumption but diminished over time. The findings on disaggregated energy showed that urbanization leads to increase in residential energy structure.

Hossain's (2011) study investigated the causal relationship between carbon dioxide emission, energy consumption, urbanization, economic growth and trade openness covering the period between 1971 and 2007. The Johansen Fisher panel cointegration revealed an existence of a long run relationship among the variables. The granger-causality results discovered only short run causalities: From trade openness to carbon dioxide emission, from economic growth to energy consumption, from urbanization to economic growth and from trade openness to urbanization.

Another study that incorporated trade openness in investigating the nexus between energy consumption and urbanization was undertaken by Kasman and Duman (2015). A panel data of new EU member and candidate countries for the period between 1992 and 2010 was employed. The long run granger-causality results indicated that gross domestic product, energy consumption, carbon dioxide emissions and trade openness granger-cause each other. It was also revealed that urbanization, trade openness and energy consumption granger-cause carbon dioxide emissions in the short run. The results further suggested a unidirectional causality flowing from urbanization to trade openness in the short run.

Kasman and Duman (2015) investigated the causal relationship between urbanization, energy consumption and carbon dioxide emissions in the Sub-Saharan countries for the period from 1985 to 2010. The study used Pedroni and Kao co-integration and established that there is a long run relationship between the variables. It further employed the VECM granger-causality which validated bidirectional causality flowing between energy consumption and carbon dioxide emission and, between energy consumption and urbanization.

Zhao and Wang (2015) undertook a study to examine the link between urbanization, economic growth and energy consumption in China. The data used covered the period 1980-2012. The co-integration results indicated that there is a long run relationship between energy consumption, urbanization and economic growth in China. The VECM results reported bidirectional causality flowing between economic growth and energy consumption and a unidirectional causality running from urbanization to energy consumption and from economic growth to urbanization.

Wang et al. (2014) carried a study to determine the relationship between urbanization, energy consumption and carbon dioxide emissions for 30 Chinese provinces using a panel data over the period 1995-2011. It was discovered that urbanization, energy consumption and carbon dioxide emission have a long run positive relationship. There is a feedback hypothesis established between carbon dioxide emissions and urbanization and between energy consumption and carbon dioxide emissions. Furthermore, a unidirectional causality flowing from urbanization to energy consumption was found.

Wang et al. (2016) applied the Pedroni panel co-integration test to investigate the relationship between urbanization, energy consumption and carbon dioxide emissions. The annual data for Association of Southeast Asian Nations countries was employed covering the period of 1980-2009. The results validated that urbanization, energy consumption and carbon dioxide emissions are co-integrated. The Granger-causality results showed a unidirectional causality flowing from urbanization and energy consumption to carbon dioxide emissions in the long run. It was found that urbanization granger-causes both energy consumption and carbon dioxide emissions in the short run.

Rafiq et al. (2016) explored the impact of urbanization and trade openness on carbon dioxide emissions and energy intensity in 22 increasingly urbanized emerging countries. This study employed two conceptual frameworks; STIRPAT and Environmental Kuznets Curve models. The empirical results validated that trade openness significantly decreases emissions and energy intensity. It was further established that urbanization significantly raises energy intensity but insignificantly increases emissions.

There are studies that focused on other sources of energy such as electricity consumption. Solarin and Shahbaz (2013) studied the causal relationship between electricity consumption, urbanization and economic growth in Angola using the data over the period between 1971 and 2009. The study employed the ARDL technique to determine co-integration among the variables and the VECM to determine the direction of causality between the variables. The ARDL results showed that energy consumption, urbanization and economic growth are co-integrated. The VECM results detected bidirectional causality between urbanization and electricity consumption. Economic growth and urbanization were also found to granger-cause each other. Finally, a feedback hypothesis was established between economic growth and electricity consumption.

Shahbaz et al. (2014) purposed to dismantle the nexus between economic growth, electricity consumption, urbanization and environmental degradation in the United Arab Emirates. The quarterly data covering the period 1975-2011 was used. The ARDL bounds test results showed a long run relationship among the variables. Electricity consumption is found to negatively affect carbon dioxide emissions while urbanization positively affects carbon dioxide emissions. The VECM results validated bidirectional causality between electricity consumption and carbon dioxide emissions while economic growth and urbanization granger-cause carbon dioxide emissions.

Liddle and Lung (2013) explored the relationship between electricity consumption and urbanization in 105 countries over the period of 1971-2009. The granger-causality results revealed a unidirectional causality flowing from electricity consumption to urbanization. This implies that the employment and quality of life which are made possible by access to electricity can influence migration to cities.

From the empirical literature, it can be realized that most studies concentrated on developed countries. Particularly, no study was done in South Africa to explore the impact of urbanization on electricity consumption controlling for economic growth and carbon dioxide emissions. Therefore, this study serves to fill the gap.

3. METHODOLOGY

3.1. Data Collection and Variables

This study employs annual time series data over the period of 1971-2013 for South Africa. In order to empirically investigate the impact of RUDT on electricity consumption, the study opt for a set of five variables. This includes electricity consumption, RUDT, trade openness, labour and capital formation. The variables used in the study are measured as follows: Electricity consumptions is measured in Kwh, RUDT is measured by urbanization, trade openness is the combination of exports and imports, employment is measured by labor productivity per person employed in 2015 US$ and capital is gross capital formation (constant 2010 US$). The annual data available from 1971 to 2013 on electricity consumption, RUDT and capital were sourced from the World Development Indicators published by the World Bank (WB, 2016) while data for labour was extracted from The Conference Board (2016) and data for trade openness was collected from United Nations and Trade Development (UNCTAD). Electricity consumption is taken as the dependent variable while RUDT, trade openness, labour and capital are dependent variables.

3.2. Model Specification

The aim of this study is to examine the impact of RUDT on electricity consumption using production function. This study incorporated trade openness, labour and capital as additional determinants of electricity consumption and RUDT. Therefore, the log-linear form of the model can be molded as follows:

$$Ec_t = f(UBN_t, TO_t, L_t, L_t, K_t) \qquad (1)$$

Ahamad et al. (2013) posit that log-linear specification gives consistent and reliable results. Therefore, all the variables are transformed into logarithmic form. Equation (1) can be modeled for analysis as follows:

$$LEC_t = \alpha + \beta_1 LUBN_t + \beta_2 LTO_t + \beta_3 LL_t + \beta_4 LK_t + \mu_t \qquad (2)$$

Where, LEC represents the natural log of electricity consumption, LUBN is the natural log of RUDT, LTO denotes natural log of trade openness, LL represents the natural log of employment and LK denotes the natural log of capital formation. There are three steps involved in estimating the interdependencies. The first step is to determine the stationarity of the variables. The second step involves investigating the long run relationship among the variables. The last step involves finding the direction of causality flowing between the variables.

3.3. Unit Root

The first step in examining the long run relationship between the variables is to test whether the variables are stationary or non-stationary. If all the variables are stationary, the test of co-integration can be done but otherwise, more care is required. For the purpose of this study, the augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) unit root tests are used. The ADF test has advantage over other methods because it can control for the serial correlation problem associated with the variables. ADF test can be represented as follows:

$$\Delta Y_t = \alpha Y_{t-1} + \theta_t \delta + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta Y_{t-1} + \ldots \beta_p \Delta Y_{p-t} + \upsilon_t \qquad (3)$$

The null hypothesis and alternative hypothesis are formulated as follows:

H_0: $\alpha = 0$

H_1: $\alpha < 0$

The null hypothesis states that all the series are non-stationary and tested against the alternative hypothesis that fraction of the series are assumed to be stationary. The T-statistics is used to test whether the null hypothesis is rejected or not.

3.4. Co-integration

When the variables are found to be integrated of the same order, the next step is to determine whether they are co-integrated. But before testing for co-integration, it is necessary to estimate the lag order. The optimal lag structure of the first difference regression is selected based on akaike information criteria (AIC). The ARDL model estimates $(p+1)^k$ number of regressions to select the optimal model, where p represents the maximum number of lags and k is the number variables.

This study uses the Johansen test of co-integration to explore the long run relationship between electricity consumption, RUDT, trade openness, labour and capital. The Johansen cointegration technique employs the maximum likelihood procedure which comprises of significantly large and finite sample size and offers robust empirical evidence than engle and granger co-integration test. Therefore, to investigate the relationship between electricity consumption and RUDT, Johansen test of cointegration is preferred.

This technique involves the estimation of a VECM to estimate the likelihood-ratios (LR). It works in a way that there are at most n-1 cointegrating vectors if there are n variables which all have unit roots. The VECM model employed in this study is as follows:

$$\Delta Y_t = \theta_0 + \sum_{i=1}^{k-1} \theta_i \Delta Y_{t-1} + \propto \beta^{'Y_{t-k}} + \varepsilon_t \qquad (4)$$

Where, Δ is the difference operator, Y_t is (LGDP, LESSR, LCO2, LEM, LK), Θ is stands for the intercept and $\mathcal{E}$ is the vector of white noise process.

The Johansen cointegration technique comprises of two tests statistics namely; maximum Eigen value test and trace test. Each test separately examines the number of co-integrating vectors. If the results established different numbers of co-integrating vectors, then the results found by the maximum Eigen value test are preferred.

3.4.1. Granger-causality

The next stage of the analysis, the VECM analysis investigate the long run and short causality between electricity consumption and RUDT. Time series X granger-causes times series Y if the prediction error of series Y changes based on the previous value of X and Y. The VECM can be molded as follows:

$$\Delta LEC_t = \alpha_{10} + \sum_{i=1}^{q} \alpha_{11} \Delta LEC_{t-i} + \sum_{i=1}^{r} \alpha_{12} \Delta LUBN_{t-i} + \sum_{i=1}^{s} \alpha_{13} \Delta LTO_{t-i} + \sum_{i-1}^{t} \alpha_{14} \Delta LL_{t-i} + \sum_{i-1}^{u} \alpha_{15} \Delta LK_{t-i} + \psi_1 ECT_{t-1} + \varepsilon_{1t} \quad (5)$$

$$\Delta LUBN_t = \alpha_{20} + \sum_{i=1}^{q} \alpha_{21} \Delta LUBN_{t-i} + \sum_{i=1}^{r} \alpha_{22} \Delta LEC_{t-i} + \sum_{i=1}^{s} \alpha_{23} \Delta LTO_{t-i} + \sum_{i-1}^{t} \alpha_{24} \Delta LL_{t-i} + \sum_{i-1}^{u} \alpha_{25} \Delta LK_{t-i} + \psi_2 ECT_{t-1} + \varepsilon_{2t} \quad (6)$$

$$\Delta LTO_t = \alpha_{30} + \sum_{i=1}^{q} \alpha_{31} \Delta LTO_{t-i} + \sum_{i=1}^{r} \alpha_{32} \Delta LEC_{t-i} + \sum_{i=1}^{s} \alpha_{33} \Delta LUBN_{t-i} + \sum_{i-1}^{t} \alpha_{34} \Delta LL_{t-i} + \sum_{i-1}^{u} \alpha_{35} \Delta LK_{t-i} + \psi_3 ECT_{t-1} + \varepsilon_{3t} \quad (7)$$

$$\Delta LL_t = \alpha_{40} + \sum_{i=1}^{q} \alpha_{41} \Delta LL_{t-i} + \sum_{i=1}^{r} \alpha_{42} \Delta LEC_{t-i} + \sum_{i=1}^{s} \alpha_{43} \Delta LUBN_{t-i} + \sum_{i-1}^{t} \alpha_{44} \Delta LTO_{t-i} + \sum_{i-1}^{u} \alpha_{45} \Delta LK_{t-i} + \psi_4 ECT_{t-1} + \varepsilon_{4t} \quad (8)$$

$$\Delta LK_t = \alpha_{50} + \sum_{i=1}^{q} \alpha_{51} \Delta LK_{t-i} + \sum_{i=1}^{r} \alpha_{52} \Delta LEC_{t-i} + \sum_{i=1}^{s} \alpha_{53} \Delta LUBN_{t-i} + \sum_{i-1}^{t} \alpha_{54} \Delta LTO_{t-i} + \sum_{i-1}^{u} \alpha_{55} \Delta LL_{t-i} + \psi_5 ECT_{t-1} + \varepsilon_{5t} \quad (9)$$

Δ represent the difference operator, α_{it} is the constant term and error correction term refers to the error correction term derived from the long run cointegrating relationships. The short run causality running from urbanisation to electricity consumption could be determined by the F-statistics of the joint significance of the lagged ΔUBN_t coefficients in Equation (5). In the same way, short run causality flowing from electricity consumption to urbanisation can be estimated by the F-statistics for the joint significance of the lagged ΔEC_t coefficients in Equation (6). The long run causality flowing from urbanisation to electricity consumption can derived from the significance of the error correction term coefficient in Equation (5). Similarly, the significance of the error correction term coefficient in Equation (6) could be explained as a long run causality running from electricity consumption to urbanisation.

4. FINDINGS

The two unit root tests were employed to determine the unit root process of the time series data, namely; the ADF unit root test and the PP unit root test. The findings of these tests are illustrated in Table 1.

At level form, the null hypotheses of stationarity are rejected at 5% level of significance. This implies that all the variables are not stationary at levels. Table 1 further shows that at first difference, the null hypothesis of stationarity cannot be rejected at 5% level of significance. This means that the variables are stationary when differenced once.

4.1. Co-integration

The Johansen test of co-integration is based on the assumption that all the variables should be integrated of the same order. On this account, Johansen test of co-integration will be used to determine the existence of the long run relationship between electricity consumption, urbanisation, trade openness, labour and capital. But prior to investigating the long run relationship between the variables, it is necessary to find the optimal lag length. The AIC is used to determine the optimal lag length. The results are shown in Table 2 and reveal that the optimal lag length P* = 3 is chosen.

Table 3 presents the results of the Johansen test of co-integration. The trace test results report that there are five co-integrating long run relationship. This is because for $r = 0$, $r \leq 1$, $r \leq 2$, $r \leq 3$, $r \leq 4$, maximal trace statistics are 122.7, 65.7, 40.0, 16.7 and 4.9, which are greater than the 95 per cent critical values of 69.8, 47.9, 29.8, 15.5 and 3.8, respectively. But the maximum Eigen value test indicate that there is only one co-integrating long run relationship. This is on account that for $r = 0$, the λ max statistics is 57.0, which is more than the 95% critical value of 33.9. As indicated in section 3, when the two tests show different results, the maximum Eigen value test is preferred. The study, therefore concludes that there is one co-integrating long run relationship. These results suggest that there is a long run relationship between electricity consumption, urbanisation, trade openness, labour and capital in South Africa. This confirms the results by Hossain (2011) and Kasman and Duman (2015).

Having established the existence of co-integration among the variables, the next stage is to estimate the long run coefficients. The results for the long run coefficients are illustrated in Table 4.

Table 1: Unit root tests

Variables	ADF unit root test		PP unit root test	
	Levels	1st difference	Levels	1st difference
LEC	−1.8418	−5.6057*	−1.9102	−5.5567*
LUBN	−1.7675	−2.0591**	−1.3083	−1.3742**
LTO	−2.1026	−5.4221*	−2.0581	−5.4427*
LL	−0.8752	−4.2924*	−1.3921	−4.2726*
LK	−0.8374	−4.9103*	−1.1225	−3.0716**

Source: Own calculation. ADF: Augmented Dickey-Fuller

Table 2: Selection order criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	319.6731	NA	1.01e-13	−15.73366	−15.52255	−15.65733
1	677.8786	608.9492	5.94e-21	−32.39393	−31.12727*	−31.93594
2	717.7323	57.78793	3.01e-21	−33.13662	−30.81441	−32.29698
3	755.5105	45.33377*	1.87e-21*	−33.77552*	−30.39776	−32.55423*

Source: Own calculation. AIC: Akaike information criteria

Table 3: Johansen co-integration

H_1: Alternative hypothesis	H_0: Null hypothesis	λ_{max} test	λ_{max} test (0.95)	Trace test	Trace test (0.95)
r=1	r=0	57.0083	33.8769	122.700	69.8189
r=2	r≤1	25.7389	27.5843	65.6918	47.8561
r=3	r≤2	23.2625	21.1316	39.9528	29.7871
r=4	r≤3	11.8080	14.2646	16.6903	15.4947
r=5	r≤4	4.8824	3.8415	4.8824	3.8415

Source: Own calculations

Table 4 shows that urbanisation is positively and significantly related to electricity consumption. The relationship is such that a 1 percent increase in urbanisation leads to an increase of 1.2% in electricity consumption, all else held constant. These results are consistent with the findings of Lin (2009), Hossain (2011), Solarin and Shahbaz (2013) and Zhang and Lin (2012).

Furthermore, it was discovered that trade openness is positively and significantly related to electricity consumption. All else the same, a 1 percent increase in trade openness is linked with 0.6 percent increase in electricity consumption. These results are consistent to the ones found by Kasman and Duman (2015) and Hossain (2011).

Labour was found to have a positive impact on electricity consumption while capital negatively affects electricity consumption contrary to economic theory. It was established that a 1% increase in labour increases electricity consumption by 0.4%, ceteris paribus. Contrarily, a 1% increase in capital is associated with a fall in electricity consumption, all else the same.

The short run results are presented in Table 5. The results posit that there is a positive and significant short run relationship between urbanisation and electricity consumption; trade openness and electricity consumption, and labour and electricity consumption. The relationships are such that, ceteris paribus, a 1% increase urbanisation, trade openness and labour are associated with an increase in electricity consumption on an average of 1.0%, 0.4% and 0.6%, respectively. Finally, the results suggest that capital has a negative and significant relationship with electricity consumption.

The lagged error term i.e.,- ECM_{t-1} (−0.78) is found to have an expected negative sign and statistically significant at 1% level of significance. These results confirm the existence of the long run relationship between electricity consumption, urbanisation, trade openness, labour and capital formation. The results indicate that the short run deviations from long run equilibrium are corrected by 78% towards long run equilibrium each year.

4.2. Granger-causality

Since the results found existence of co-integration among the variables, this indicates that there is existence of causality. To determine whether there is a unidirectional or bidirectional causality, the VECM is applied and the results are illustrated in Table 6. The results reveal that there is a long run Granger causality relationship flowing from urbanisation, trade openness, labour and capital to electricity consumption. This is because the coefficient of the error correction term in Equation (5) is found to be negative and significant at 1% level of significance. It was also established that the coefficient of the error correction term in Equation (9) is negative and significant at 1 percent level of significance. This is interpreted as a one-way causality flowing from electricity consumption, urbanisation, trade openness and employment to capital.

The coefficients of the error correction terms for Equation (7) and Equation (8) were found to be significant at 10% and 1% levels of

Table 4: Long run results

Dependent variable=LEC			
Long term results			
Variable	Coefficients	Standard error	t-statistics
Constant	1.114	0.845	1.319
LUBN	1.210*	0.110	10.983
LTO	0.646*	0.164	3.930
LL	0.350	0.327	1.070
LK	−0.073	0.189	−0.387
R^2	0.86		
F-statistics	58.28*		
Durbin–Watson statistics	0.59		

Source: Own calculations

Table 5: Short run analysis

Variable	Coefficient	Standard error	t-statistics
Constant	0.538	0.569	0.351
LUBN	1.015*	0.821	12.345
LTO	0.343*	0.119	2.882
LL	0.649*	0.222	2.929
LK	−0.331*	0.130	−2.531
ECM_{t-1}	−0.78*	0.116	−6.728
R^2	0.93		
F-statistics	93.20*		
Durbin–Watson test	1.50		

Source: Own calculation. *Represent 1%, significance level. ECM: Error correction model significance, respectively, but were not negative. This implies that there is no causality found flowing from electricity consumption, urbanisation, employment and capital to trade openness and from electricity consumption, urbanisation, trade openness and capital to employment in the long run. Finally, when urbanisation was considered an independent variable Equation (6), there was no causality established flowing from electricity consumption, trade openness, labour and capital to urbanisation. This is on account that the coefficient of the error correction term is neither negative nor significant.

Table 6 shows that there is a short run causality flowing from labour to trade openness. This is because the F-statistics of the joint lagged ΔL coefficients in Equation (7) is significant at 1 percent level of significance. It was further detected that trade openness and capital Granger-cause labour in the short run. Finally, a short run causality flowing from labour to capital was found.

Generally, the results established bidirectional causality flowing between electricity consumption and capital in the long run. A long run unidirectional causality flowing from urbanisation to electricity consumption was also detected. These results are consistent to the findings by Wang et al. (2014), Zhao and Wang (2015) and Liu (2009). There was no causality found flowing from electricity consumption to urbanisation.

The results were checked for stability using the variance decomposition approach. This technique is used to compare the contribution extents of various time series. The variance decomposition results of electricity consumption, urbanisation and trade openness are presented in Tables 7-9, respectively.

The variance decomposition approach findings in Table 7 posit that 61.31% portion of electricity consumption is contributed by its own innovative shocks. A one standard deviation shock in urbanisation explains electricity consumption by 12.41% while trade openness, labour and capital support electricity consumption by 15.55%, 7.37% and 3.36%, respectively.

Table 8 shows that 32.80 of urbanisation is explained by its own innovative shocks. A larger proportion of the shocks in urbanisation is explained by electricity consumption (49.52%) while the contributions of trade openness (0.78), labour (2.80%) and capital (14.10%) are low.

Table 6: VECM

Dependent variable	Types of causality					
	Short run					Long run
	∑ΔLEC	∑ΔLUBN	∑ΔLTO	∑ΔLL	∑ΔLK	ECT_{t-1}
ΔLEC		1.376	0.490	1.982	0.451	−0.025*
ΔLUBN	1.781		1.035	1.612	0.343	0.0029
ΔLTO	0.354	0.303		3.402*	0.991	0.357***
ΔLL	2.157	1.90	5.719*		4.129*	0.157*
ΔLK	1.398	0.783	1.121	2.783**		−0.355*

Source: Own calculation. VECM: Vector error correction model, ECT: Error correction term

Table 7: Variance decomposition of LOG_EC

Period	SE	LOG_EC	LOG_UBN	LOG_TO	LOG_L	LOG_K
1	0.014215	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.019714	95.67556	0.590999	0.277303	3.159479	0.296661
3	0.022985	89.27759	2.623950	2.898289	4.875274	0.324899
4	0.025129	82.68253	4.997648	5.860818	6.178889	0.280112
5	0.026826	76.85734	7.021457	8.490095	7.080633	0.550472
6	0.028272	71.91952	8.585383	10.65099	7.622805	1.221308
7	0.029509	67.96364	9.814306	12.39425	7.807439	2.020364
8	0.030538	65.00363	10.82361	13.74311	7.749203	2.680443
9	0.031387	62.86960	11.67836	14.76039	7.576243	3.115409
10	0.032097	61.30709	12.41439	15.54513	7.370033	3.363357

SE: Standard error

Table 8: Variance decomposition of LOG_UBN

Period	SE	LOG_EC	LOG_UBN	LOG_TO	LOG_L	LOG_K
1	0.000637	1.875912	98.12409	0.000000	0.000000	0.000000
2	0.001336	11.63384	85.41564	0.074849	2.869775	0.005888
3	0.002109	19.38197	74.55273	0.113082	4.957420	0.994792
4	0.002932	25.65206	64.25556	0.086824	6.241417	3.764142
5	0.003789	30.80266	55.37571	0.059638	6.435811	7.326185
6	0.004643	35.30782	48.35821	0.040455	5.849076	10.44443
7	0.005456	39.35788	43.03581	0.064650	4.952096	12.58956
8	0.006206	43.03512	38.94264	0.183856	4.068643	13.76974
9	0.006894	46.40396	35.63580	0.425593	3.339870	14.19478
10	0.007530	49.52198	32.80216	0.778728	2.799256	14.09787

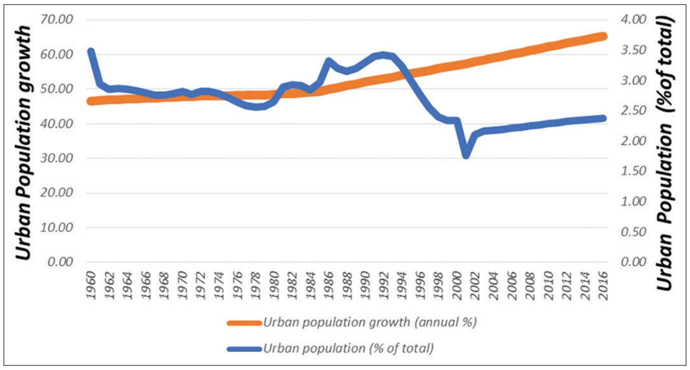
SE: Standard error

Table 9: Variance decomposition of LOG_TO

Period	SE	LOG_EC	LOG_UBN	LOG_TO	LOG_L	LOG_K
1	0.023180	16.87304	2.095682	81.03127	0.000000	0.000000
2	0.029693	22.05963	1.860543	74.11062	1.629769	0.339440
3	0.030565	20.84224	1.756561	73.98163	2.484095	0.935479
4	0.031459	24.12920	1.660131	70.33828	2.367774	1.504619
5	0.032901	28.75133	1.690398	64.70419	3.107745	1.746346
6	0.034318	31.03231	2.404281	60.14323	4.742949	1.677236
7	0.035626	31.18137	3.826918	56.66558	6.737511	1.588614
8	0.036894	30.12908	5.634481	53.71319	8.653875	1.869370
9	0.038138	28.57369	7.526916	51.06338	10.16663	2.669390
10	0.039309	26.98281	9.330145	48.72521	11.13605	3.825791

SE: Standard error

Figure 1: Urban population trends in South Africa (1960-2014)



Source: World Development Indicators (2015)

The results of variance decomposition for trade openness show that 48.73% of trade openness is explained by its own shocks (Table 9). The results further show that the contributions of electricity consumption, urbanisation, labour and capital are equal to 26.98%, 9.33%, 11.14% and 3.83%, respectively.

5. CONCLUSION

This study investigated the impact of urbanisation on electricity consumption in South Africa over the period 1971-2013. Trade openness, capital and labour were incorporated to form a multivariate framework. Prior to estimating the causality between the variables, data was tested for stationarity using the ADF unit roots test and PP unit root test. The Johansen test of co-integration was employed to determine the long run relationship among the variables. The direction of causality between electricity consumption and urbanisation was examined using the VECM.

According to ADF and PP unit root tests, the variables are found to be integrated of order one $I(1)$. The Johansen test of cointegration established that electricity consumption, urbanisation, trade openness, labour and capital move together in the long run. It was revealed that urbanisation and trade openness have a long run positive and significant impact on electricity consumption. This is consistent to the literature by the studies of Kasman and Duman (2015). This might be due to the fact that South Africa is rapidly becoming open and its taking advantage of investments that bring wealth to the citizens, hence the increase in demand for goods and services which include electricity. Labour and capital have insignificant impact on electricity consumption.

The VECM results validated a unidirectional causality flowing from trade openness, labour and capital to economic growth. Most importantly, it was established that urbanisation Granger-causes electricity consumption. These results are consistent to Zhao and Wang (2015), Lind (2009) and Wang et al. (2014). Feedback hypothesis was found flowing between electricity consumption and capital in the long run. These results have substantial policy implication as they demonstrate that urbanisation and trade openness play a vital role in increasing electricity consumption. Therefore, South Africa must take advantage of openness to access clean energy technology. This will ensure clean source of electricity and alleviate greenhouse gas emissions.

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