The causal linkages between renewable electricity generation and economic growth in South Africa.

Khobai, Hlalefang

3 May 2018

The causal linkages between renewable electricity generation and economic growth in South Africa.

Hlalefang Khobai

Department of Economics, Nelson Mandela Metropolitan University

Email: hlalefangk@gmail.com

Abstract

Knowledge of the direction of causality between electricity generation from renewables and economic growth is essential if energy policies which will support economic growth of the country are to be devised. This study explores the causal relationship between electricity generated from the renewables and economic growth in South Africa using carbon dioxide emissions, employment and capital as the additional variables. The study uses the Johansen co-integration model to detect the long run relationship between the variables and the Vector Error Correction Model (VECM) to determine the direction of causality. The findings from Johansen co-integration evidenced a long run relationship between electricity generated from renewables, economic growth, carbon dioxide emissions, employment and capital. The VECM revealed unidirectional causality running from electricity generated from renewables to economic growth. The findings indicate that electricity generation from renewables enhance economic growth. Therefore, the government should make appropriate efforts to select energy policies that do not negatively affect economic growth.

Key words: Electricity generation, carbon dioxide emissions, economic growth

JEL codes: C32, D04, Q47, Q42, Q01

---

1. INTRODUCTION

One third of the population in South Africa is still without electricity. Greenpeace (2011) blames this inadequate supply of electricity from coal and nuclear-based production of electricity on Eskom. These two generation technologies are criticised for pollution and generating greenhouse gas emissions (GHG) (Greenpeace 2013). The main debate in respect of renewable energy resources is that coal and nuclear based electricity has failed to supply millions of South Africans with electricity. One of the main causes of electricity power shortages in South Africa is the increase in the price of coal and a fall in its production.

South Africa is endeavouring to meet the increasing demand but unfortunately the focus is on building more coal-fired generating plants - Medupi and Kusile power stations. Greenpeace (2011), argued that the renewable energy is less costly and could provide universal access to electricity, but the government is not promoting it. The supporters of renewable energy resources are convinced that producing renewable energy will give South Africa the opportunity to unlock its economic growth and development (Gets & Mhlanga 2013; Greenpeace 2013; Edkins, Marquard & Winkler 2010: Greenpeace 2011).

Coal and nuclear fuels have been slated for their inefficiencies in the production of electricity (Gets & Mhlanga 2013; Greenpeace 2013; Teske *et al.* 2011). Firstly, coal is the core source of the world's CO_2 emissions and the highest polluting energy source on earth (Greenpeace 2013). The impact of climate changes caused by coal affects other industries such as water supply industry. For instance, Acid mine drainage from deserted mines impacts the quality of water in South Africa and threatens supply of the scarce water resources (Gets & Mhlanga 2013). Gets and Mhlanga (2013) further showed that Eskom utilises about 10 000 litres of water per second washing coal as well as operating power stations.

The above concerns about global climate change were discussed at the Johannesburg world summit on Sustainable Development in 2002. The participating countries were urged to commit to promoting renewable energy. South Africa was warned of its contribution to the greenhouse gas emissions. This led to South Africa committing to invest in the renewable resources.

The renewable energy resources connect naturally occurring non-exhaustible sources of energy. These types of energy sources include wind, solar, biomass, tidal, hydro, wave, geothermal and ocean currents. South Africa has an abundance of solar energy supply and is ranked among the highest in the world (Teske *et al.* 2011). South Africa is also rated amongst the highest in the world in terms of solar radiation levels. This shows that the resources are being under utilised as free energy sources are not fully exploited.

Comparing solar radiation averages for South Africa with countries such as USA and Europe, Teske *et al.* (2011) found that in the USA, an annual 24-hour solar radiation averages 150 W/m^2 and 100 W/m^2 for Europe while in South Africa, it averages to about 220 W/m^2. This ranking shows that South Africa has a high potential and this can be achieved only if the government would commit to the transition from coal and nuclear fuels to renewable energy resources.

It has been proven that increase in effectiveness and productivity within the framework of electricity generation from renewables reduces carbon dioxide emissions and stimulates economic growth over time (Ohler and Fetters 2014, Khide and Adjasi 2015, Cedeira 2012 and Bento and Moutinho 2016). The aim of this study is therefore to examine the causal link between economic growth and electricity generated from renewables in South Africa using Johansen co-integration test and Vector Error Correction Model (VECM). The study is structured as follows. The next section reviews the theoretical and empirical literature. The third section deals with data sources, explanatory variables and the econometric specification model. Section four presents the analysis of empirical results followed by section five which focuses on the conclusion and policy recommendation.

3. LITERATURE

This section focuses on reviewing the literature on investigating the causal relationship between economic growth and electricity generated from the renewables using the co-integration techniques and Granger-causality tests. The studies conducted relating to these variables differs in terms of time periods, country specific analysis and models employed. This differences leads to difference in the results of these studies and there are three possible results: bidirectional, unidirectional or no causality. The literature will be divided into three different categories.

The first category mainly deals with bivariate framewok studies. These are studies which focus on the two variables only, electricity generated from renewables and economic growth. The second category focuses on the trivariate framework. These studies add one additional variable to electricity generated from renewables and economic growth. The third category is of studies which concentrated on multivariate framework. Since not much literature has been done for electricity generation from renewables and economic growth, the study will also focus on the related studies which were done on the relationship between electricity supply and economic growth and, renewable energy consumption-economic growth nexus.

A bivariate study by Yoo and Kim (2006) investigated the relationship between electricity generation and economic growth in Indonesia for the period between 1971 and 2002. Their findings reported a unidirectional causality flowing from economic growth to electricity generation without any feedback effect. Bayraktutan *et al.* (2011) undertook a study to explore the relationship between electricity generated from renewable resources and economic growth in OECD countries covering the period 1980 – 2007. The Granger-causality findings revealed a feedback causality flowing between these variables.

Morimoto and Hope (2004) carried a study in Sri Lanka to establish the relationship between electricity generation and economic growth. Applying Yang's regression analysis, their empirical results revealed that electricity supply had a positive impact on economic growth in Sri Lanka. It is such that an increase in electricity supply by 1Mwh leads to Rs 88 000 to Rs137 000 of economic output.

Another bivariate causality study between electricity supply and economic growth relationship was done by Sarker (2010). This study used data from Bangladesh for the period between 1973 and 2006 and applied the VAR model to test for causality direction between the variables. The Granger-causality results indicated that there is one-way causality flowing from electricity supply to economic growth.

Ohler and Fetters (2014) studied a causal link between economic growth and electricity generation from the renewable sources (biomass, geothermal, hydro, wind, solar and waste) for 20 OECD countries for data covering the period 1990 – 2008. The findings exhibit bidirectional causality flowing between aggregate renewable electricity generation and economic growth. The results further posits that hydroelectricity, biomass, wind and waste energy have a positive and long run impact on economic growth.

Al-mulali et.al (2013) conducted a study to determine the dynamic relationship between renewable energy consumption and economic growth for high income, upper middle income, lower middle income and low income countries. The fully modified OLS discovered bidirectional causality flowing between renewable energy consumption and economic growth for 79% of the countries in the long run. The results further showed no causality flowing between the variables for 19% of the countries and a unidirectional causality running from economic growth to renewable energy consumption for 2% of the countries.

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

Khide and Adjasi (2015) purposed to investigate the causal link between renewable energy sources, non-renewable sources and economic growth in Nigeria covering the period between 1971 and 2013. Applying quarterly time series, the results established that the variables are co-integrated. The Granger-causality results were mixed: firstly, a unidirectional causality flowing renewable energy to economic growth; secondly, a one-way causality running from economic growth to non-renewable energy. The renewables and non-renewables were found to have a positive impact on economic growth. The relationship is that a one percent increase renewable and non-renewable energy lead to an increase in economic growth by 19% and 8%, respectively.

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

Khobai et.al (2016) investigated the link between economic growth, electricity supply, power outages and employment for South Africa covering the period 1990 - 2012. The Granger-causality results detected a unidirectional causality flowing from electricity supply and economic growth. It further showed that power outages negatively affect economic growth.

Cerdeira (2012) conducted a study to determine the relationship between electricity supply and economic growth incorporating inward foreign direct investment, carbon dioxide emissions from electricity production and population size as additional variables to form a multivariate framework. This study of Portugal employed the bounds testing approach to co-integration and the error correction model for the 1970 to 2008 period. The co-integration results revealed a long-term relationship between these variables. The Granger-causality results validated the unidirectional causality flowing from renewable electricity production to foreign direct investment in the short term. The results further evidenced bidirectional causality between renewable electricity production, real income, inward foreign direct investment and population.

Nnaji *et al.* (2013) carried out a study in Nigeria to estimate the co-integration and Granger-causality relationship between economic growth, electricity supply, fossil fuel consumption and CO_2 emissions. The study employed data for the period 1971 to 2009. The empirical findings from the co-integration tests detected a long-term relationship between these variables. Electricity supply is also found to be positively related to CO_2

emissions indicating that there is insufficient supply of electricity in the country. The Granger-causality results revealed that a weak causality existed from electricity supply to economic growth. Therefore, it is important that more investment should be focused toward improving electricity supply in order to enhance economic growth in Nigeria.

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

Bento and Moutinho (2016) studied the link between economic growth, renewable electricity production, non-renewable electricity production, carbon dioxide emissions and international trade for Italy for the period 1960 - 2011. The ARDL bounds testing approach detected a long run relationship between the variables. The results established a unidirectional causality flowing from economic growth to renewable electricity production. It was detected that renewable electricity production leads to reduction in carbon dioxide emissions in both long run and short run.

Salim *et.al's* (2014) study aimed to examine the relationship between economic growth, renewable energy consumption, non-renewable energy consumption and industrial output in OECD countries employing data over the period between 1980 and 2011. The results reported existence of a long run relationship between economic growth, renewable energy consumption, non-renewable energy consumption and industrial output. The Granger-causality found bidirectional causality between renewable and non-renewable energy consumption and, between economic growth and non-renewable energy consumption. It further realised a one-way causality flowing between economic growth and renewable energy consumption.

3. METHODOLOGY

3.1 Data Collection

This study utilises quarterly time series data covering the period of 1997Q1 – 2012Q4 for South Africa. In order to empirically explore the relationship between electricity generated from the renewables and economic growth, carbon dioxide emissions, employment and capital are added to form a multivariate framework. The variables used in the study are measured as follows: Gross domestic production (GDP) per capita at 2010 constant prices, the carbon dioxide emissions are measured in metric tons per capita, electricity generated from renewables is measured in Kwh, 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 1996 to 2013 on economic growth, electricity generated from renewables, carbon dioxide emissions and capital was extracted from the World Development Indicators (WDI) published by the World Bank (WB 2016) while data for employment which was sourced from The Conference Board (2016). The variables annual data is transformed into quarter frequency using the Lisman matrix. This led to the study having 64 observations on each series ranging from 1997Q1 to 2012Q2. All the variables in this study have been converted into natural logarithmic form.

3.2 Model specification

The model specification to determine the causal relationship between electricity generated from renewables, economic growth, carbon dioxide emissions, employment and capital formation is based on a simple multivariate framework where the link is represented as follows:

$$LGDP_t = \alpha + \beta_1 LESSR_t + \beta_2 LCO2_t + \beta_3 LEM_t + \beta_4 LK_t + \mu_t \quad (1)$$

Where: LGDP represents economic growth, LESSR is the electricity generated from renewables, CO2 represents carbon dioxide emissions, EM is employment and K is the 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.

3.2.1 Unit root

Following from the studies of Bento and Moutinho (2016), Ahmad and Islam (2011), Khobai et.al (2016) and Nnaji et.al (2013) this study uses both the Augmented Dickey Fuller (ADF) and Phillips and Perron (PP) unit root test. The choice of ADF is based on the fact that it can control for the serial correlation problem associated with the variable. Since this study uses the time series, it is necessary to test for stationarity of the variables. This is because time series necessitates that each underlying series must be stationary to avoid spurious regression. ADF test can be represented as follows:

$$\Delta Y_t = \alpha Y_{t-1} + \theta_t \delta + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta Y_{t-2} + \ldots \beta_p \Delta Y_{p-t} + \upsilon_t \qquad (2)$$

Equation (2) above was used to test

the null hypothesis H_0: $\alpha = 0$, which implies that there is no unit root.

against

the alternative hypothesis H_1: $\alpha < 0$, which means there is unit root.

To test whether the null hypothesis is rejected or not, the T-statistics is used.

3.2.2 Co-integration

To estimate the long run relationship between the variables, we employ Johansen co-integration approach. It is chosen over Engle and Granger co-integration because it applies the maximum likelihood procedure which contains significantly large and finite sample size. It also provides robust empirical evidence. The Johansen test of co-integration is used to determine the number of co-integrating vectors of equations. This technique involves the estimation of a Vector Error Correction Model (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:

$$\Delta Y_t = \theta_0 + \sum_{i=1}^{k-1} \theta_i \, \Delta Y_{t-1} + \propto \beta'^{Y_{t-k}} + \varepsilon_t \qquad (3)$$

Where Δ is the difference operator, Y_t is (LGDP, LESSR, LCO2, LEM, LK), *Ɵ* is stands for the intercept and Ɛ is the vector of white noise process

It comprises of two test statistics; the Maximum eigen value test and Trace test. The number of co-integrating vectors in the system is determined by the number of significant non-zero eigen values. In the case where the two tests report different results, the maximum eigen value is preferred.

3.2.3 Granger-causality

After examining the long run relationship between the variables, the Granger-causality is applied to find the direction of causality among the variables. If the results detect existence of a long run relationship, the Vector Error Correction Model is used to estimate the direction of causality. On the other hand, if the variables are not co-integrated, the Vector Autoregression (VAR) model is applied. The VECM is used to determine the long run and short run relationship between the variables and can detect sources of causation. The VECM is molded by Eq. (4) – Eq.(8). In each equation, the dependent variable is explained by itself, the independent variables and the error correction term.

$$\Delta LGDP_t = \alpha_{10} + \sum_{i=1}^{q} \alpha_{11} \Delta LGDP_{t-i} + \sum_{i=1}^{r} \alpha_{12} \Delta LESSR_{t-i} + \sum_{i=1}^{s} \alpha_{13} \Delta LCO2_{t-i} + \sum_{i-1}^{t} \alpha_{14} \Delta LK_{t-i} + \sum_{i-1}^{u} \alpha_{15} \Delta LEM_{t-i} + \psi_1 ECT_{t-1} + \varepsilon_{1t} \quad (4)$$

$$\Delta LESSR_t = \alpha_{20} + \sum_{i=1}^{q} \alpha_{21} \Delta LESSR_{t-i} + \sum_{i=1}^{r} \alpha_{22} \Delta LCO2_{t-i} + \sum_{i=1}^{s} \alpha_{23} \Delta LGDP_{t-i} + \sum_{i-1}^{t} \alpha_{24} \Delta LK_{t-i} + \sum_{i-1}^{u} \alpha_{25} \Delta LEM_{t-i} + \psi_2 ECT_{t-1} + \varepsilon_{2t} \quad (5)$$

$$\Delta LCO2_t = \alpha_{30} + \sum_{i=1}^{q} \alpha_{31} \Delta LCO2_{t-i} + \sum_{i=1}^{r} \alpha_{32} \Delta LESSR_{t-i} + \sum_{i=1}^{s} \alpha_{33} \Delta LGDP_{t-i} + \sum_{i-1}^{t} \alpha_{34} \Delta LK_{t-i} + \sum_{i-1}^{u} \alpha_{35} \Delta LEM_{t-i} + \psi_3 ECT_{t-1} + \varepsilon_{3t} \quad (6)$$

$$\Delta LK_t = \alpha_{40} + \sum_{i=1}^{q} \alpha_{41} \Delta LK_{t-i} + \sum_{i=1}^{r} \alpha_{42} \Delta LESSR_{t-i} + \sum_{i=1}^{s} \alpha_{43} \Delta LCO2_{t-i} + \sum_{i-1}^{t} \alpha_{44} \Delta LGDP_{t-i} +$$

$$\sum_{i-1}^{u}\alpha_{45}\Delta LEM_{t-i}+\psi_5 ECT_{t-1}+\varepsilon_{5t} \quad (7)$$

$$\Delta LEM_t=\alpha_{50}+\sum_{i=1}^{q}\alpha_{51}\Delta LEM_{t-i}+\sum_{i=1}^{r}\alpha_{52}\Delta LESSR_{t-i}+\sum_{i=1}^{s}\alpha_{53}\Delta LCO2_{t-i}+\sum_{i-1}^{t}\alpha_{54}\Delta LGDP_{t-i}+$$

$$\sum_{i-1}^{u}\alpha_{55}\Delta LK_{t-i}+\psi_5 ECT_{t-1}+\varepsilon_{5t} \quad (8)$$

Δ represent the difference operator, α_{it} is the constant term and ECT refers to the error correction term derived from the long run cointegrating linkages. The short run causal relationships are captured through the coefficients of the independent variables. This is determined using a standard Wald statistics. The long run causal relationships are based on the error correction terms. The t-statistics is employed to test the significance of the speed of adjustment in ECT terms. If the coefficients of the error correction term are negative and significant, then there is evidence of a long run causal relationship.

4. FINDINGS OF THE STUDY

4.1 Unit root tests

The Johansen test of co-integration requires the variables to be stationary at the first difference. As a result, ADF unit root and PP unit root tests are used to determine whether the variables are stationary or not at first different. Table 5.1 reports that all the variables are non-stationary at levels under both the ADF and PP unit roots tests. The results further reveal that all the variables are stationary at first difference rejecting the null hypothesis at 5 percent level of significance under PP and under ADF except for capital and employment which reject the null hypothesis at 10 percent level of significance. Generally, the results show that all the variables are stationary at first difference.

Table 1: Unit root tests

Variables	**ADF unit root test**				**Phillips-Perron unit root test**			
	Intercept		Intercept and trend		Intercept		Intercept and trend	
	Levels	Δ	Levels	Δ	Levels	Δ	Levels	Δ
LESSR	-1.166	-4.773*	-3.702	-4.415*	-3.457	-6.563*	-4.073	-6.374*
LGDP	-0.943	-4.115*	-1.136	-4.102*	-0.812	-24.49*	-7.683	-24.10*
LCO2	-1.867	-2.758**	-2.436	-2.724**	-3.4849	-16.63*	-4.181	-16.495*
LEM	-1.785	-2.418***	-2.590	-2.584***	-3.776	-24.45*	-7.026	-27.17*
LK	-0.627	-2.093***	-2.663	-2.064***	-0.382	-12.44*	-2.654	-12.95*

Source: Own calculation

4.2 CO-INTEGRATION

Since the variables are found to be stationary at first difference, the Johansen co-integration is employed. But before examining the long run relationship between the variables, the optimal lag length is determined using the Akaike information criteria and Schwartz Criteria. The results are illustrated in Table 4.2. Table 4.2 reports that the optimal lag length p*=2 is chosen.

Table 4.2 Selection order criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	645.5035	NA	5.22e-16	-21.00012	-20.82709	-20.93231
1	981.4847	605.8676	1.95e-20	-31.19622	-30.15808	-30.78936
2	1086.424	172.0309	1.44e-21	-33.81717*	-31.9139*	-33.07127
3	1121.915	52.36382*	1.07e-21*	-34.16113	-31.39277	-33.0762*

Source: Own calculation

The results of the Johansen test of co-integration are reported in Table 4.3. The results reveal that there is one co-integrating long run relationship. This is because for r=0, the λ max statistics is 66.55, which is more than the 95 percent critical value of 33.88. On the other hand, maximal Trace statistics is 111.25, which is greater than the 95 per cent critical value of 69.82. This indicate that economic growth, electricity generated from renewables, carbon dioxide emissions, employment and capital are co-integrated. This results are consistent to the findings of Salim et.al (2014), Bento and Moutinho (2016), Nnaji et.al (2013), Cerdeira (2012), Khide and Adjasi (2015) and, Ohler and Fetters (2014).

Table 4.3 JOHANSEN CO-INTEGRATION TEST

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	66.55	33.88	111.25	69.82
R=2	R≤1	24.38	27.58	44.70	47.86
R=3	R≤2	14.63	21.13	20.33	29.80
R=4	R≤3	5.61	14.26	5.70	15.50
R=5	R≤4	0.09	3.84	0.09	3.84

Source: Own Calculation

4.3 Granger-causality

The direction of causal relationship is investigated using the VECM Granger-causality presented in Eq. (4) to Eq. (8) and the findings are represented in Table 4.4. In model 1, where economic growth is the dependent variable, the coefficient of the error correction term is found to be negative and significant at 1 percent level of significance. This implies that there is a unidirectional causality flowing from electricity generated from renewables, carbon dioxide emissions, employment and capital to economic growth in the long run. The results of the Wald test suggest that there is a short run causality running from carbon dioxide emissions, employment and capital to economic growth. The findings are consistent with the results found by Bayraktutan et.al (2011), Sarker (2010), Khide and Adjasi (2015), Cerdeira (2012) and Nnaji et.al (2013).

Models three and four, where carbon dioxide emissions and employment are dependent variables, respectively, have coefficients of the error corrections terms which are negative and significant at 1 percent level of significance. This indicates that there is a long run causality flowing from economic growth, electricity generated from renewables, carbon dioxide emissions and capital to employment and also running from economic growth, electricity generated from renewables, employment and capital to carbon dioxide emissions. The Wald test results posit that there is a short run causality flowing from economic growth, carbon dioxide emissions and capital to employment and from economic growth, employment and capital to carbon dioxide emissions. The results are similar to Bento and Moutinho's (2016) findings.

Models two and five (where electricity generated from renewables and capital) failed to reveal a long run causalities from economic growth, carbon dioxide emissions, employment and capital to electricity generated from the renewables and from economic growth, electricity generated from renewables, carbon dioxide emissions and employment to capital because the coefficients of the error correction terms were found to be significant at 1 percent level of significance but not negative. The Wald test detected a unidirectional short run causality flowing from capital to electricity generated from renewables and a one-way short run causality flowing from economic growth, carbon dioxide emissions and employment to capital. These findings are similar to the results revealed by Ghosh (2009), Khobai et.al (2016) and Al-mulali et.al (2013) for 19% of the countries they studied.

Table 4.4 Granger-causality

Dependent variable	Types of Causality					
	Short run					Long run
	∑ΔLgdp	∑ Δlessr	∑ Δlco2	∑ Δlem	∑ Δlk	ECT_{t-1}
ΔLgdp	……..	2.75	17.01*	14.88*	16.11*	-1.88*
Δlessr	4.57	………	3.57	3.52	6.62*	0.12*
Δlco2	11.43*	4.42	………….	13.39*	12.01*	-0.97*
Δlem	13.37*	2.98	17.64*	……….	15.98*	-0.13*
Δlk	6.72*	3.23	9.81*	9.53*	………	0.94*

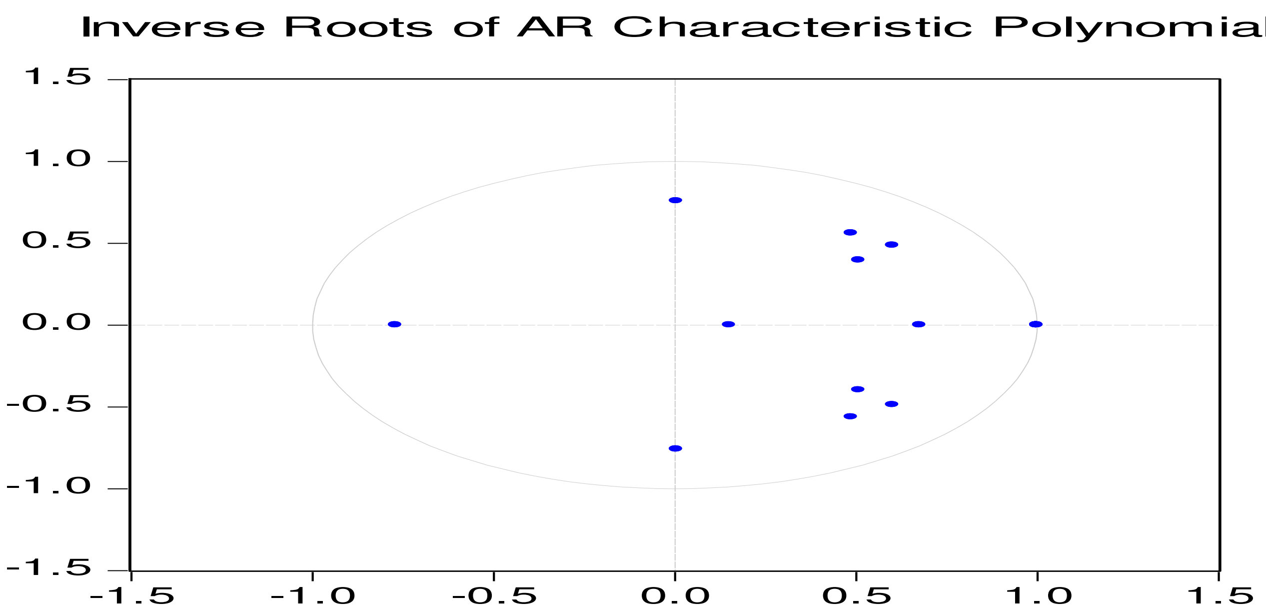
Source: Own Calculation

Generally, the VECM Granger causality results reported bidirectional causality flowing between economic growth and carbon dioxide emissions; between carbon dioxide emissions and employment and between economic growth and employment in the long run. There is a one-way long causality found flowing from electricity generated from renewables to economic growth without feedback. The following short run bidirectional causalities were established: between economic growth and carbon dioxide emissions, between economic growth and employment, between economic growth and capital, between carbon dioxide emissions and employment, between carbon dioxide emissions and capital and between employment and capital. Finally, a unidirectional causality running from capital to electricity generated from renewables was detected.

4.4 Stability Test

The VECM model was tested for its stability and stationarity using Inverse Roots of AR characteristics Polynomials (figure 4.1). A stable VECM should have the inverse roots that are within 1 point (that is the dots must fall within the circle) for it to be regarded as stable.

Figure 4.1: Inverse Roots of AR characteristic polynomial



The inverse roots of AR characteristic polynomials established the stability of the VECM system as all the dots are in the circle. As a result, the findings are highly reliable as they estimated by a stable VECM system.

The results further check with variance decomposition approach. This technique is used to compare the contribution extents of various time series. The variance decomposition results of economic growth, electricity generated from the renewables and carbon dioxide emissions are presented in Tables 4.5, 4.6 and 4.7, respectively.

Table 4.5. Variance decomposition of LGDP

Period	S.E	LDGP	LESSR	LCO2	LEM	LK
1	0.017248	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.020171	73.66373	5.488100	3.048290	4.890742	12.90914
3	0.021297	67.53343	4.924125	2.779075	13.18335	11.58002
4	0.022302	65.91083	4.524378	2.754870	14.13002	12.67990
5	0.025176	70.67768	3.648071	2.702526	11.30738	11.66434
6	0.026552	67.13089	3.964865	3.881704	10.98923	14.03331
7	0.027323	66.24300	3.754266	4.061222	12.27057	13.67094
8	0.028112	65.51639	3.571521	4.078914	13.04425	13.78893
9	0.029308	66.14700	3.363157	3.972904	12.92483	13.59210
10	0.030284	65.14951	3.425761	4.122360	13.06727	14.23510

Table 4.5 shows that 65.15% of economic growth is explained by its own innovative shocks whereas the contributions of electricity generated from renewables (3.42%), carbon dioxide emissions (4.12%) and employment (13.06%) are low compared to those of capital (14.24%) to economic growth.

Table 4.6 Variance decomposition of LESSR

Period	S.E	LDGP	LESSR	LCO2	LEM	LK
2	0.053326	19.31419	78.43549	0.148083	0.203567	1.898668
3	0.074687	14.53127	84.03264	0.207896	0.104610	1.123583
4	0.094823	15.05652	83.27069	0.189680	0.620685	0.862431
5	0.112074	17.56490	80.07025	0.141766	1.037640	1.185446
6	0.123504	16.61149	80.53444	0.118579	0.928411	1.807077
7	0.132077	15.57322	80.19532	0.117243	0.829187	3.285025
8	0.139745	14.75565	80.07068	0.122815	0.772136	4.278720
9	0.147631	14.37677	80.04678	0.114339	0.695656	4.766449
10	0.155625	13.86004	80.53552	0.105189	0.627473	4.871781

The variance decomposition approach findings in Table 4.6 posit that a 80.54 percent portion of electricity generated from renewables is contributed by its own innovative shocks. A one standard deviation shock in carbon dioxide emission explains electricity generated from renewables by 0.11 percent while economic growth, employment and capital support electricity generated from renewables by 13.86 percent, 0.63 percent and 4.87 percent, respectively

Table 4.7 Variance decomposition of LCO2

Period	S.E	LDGP	LESSR	LCO2	LEM	LK
2	0.021531	56.03010	11.81174	18.52428	4.463749	9.170137
3	0.026746	36.31776	9.563697	39.47697	8.693066	5.948500
4	0.031032	27.24332	8.732163	50.29017	7.470394	6.263952
5	0.035027	26.77081	7.726262	51.83055	5.884642	7.787737
6	0.037641	23.81012	7.490428	51.06261	5.199069	12.43778
7	0.039612	22.05891	6.783637	52.05130	5.065730	14.04042
8	0.041704	20.54323	6.125958	52.42695	4.866054	16.03780
9	0.044030	20.05522	5.524665	52.40868	4.575905	17.43553
10	0.046275	18.90737	5.152045	52.46023	4.409371	19.07098

The results of variance decomposition for carbon dioxide emissions show that 52.46 percent of the carbon dioxide emissions are explained by its own shocks (see Table 4.7). The results further show that the contributions of economic growth, electricity generated from renewables, employment and capital are equal to 18.91%, 5.15%, 4.41% and 19.07%, respectively.

6. CONCLUSION

This study used co-integration technique, causality analysis and variance decomposition approach to investigate the link between economic growth, electricity generation from renewables, carbon dioxide emissions, employment and capital for South Africa. Quarterly data for the period 1997 – 2012 was used in this study. The ADF and PP unit root tests were employed to test for stationarity of the series. The findings from the ADF and PP unit root tests indicated that all the variables are non-stationary at level form but differenced one, they became stationary.

To determine the long run relationship between the variables, the Johansen test of co-integration was applied. The Johansen test discovered that the variables are co-integrated. The study employed the VECM to determine the direction of causality between the variables. The VECM Granger causality results reported bidirectional causality flowing between economic growth and carbon dioxide emissions; between carbon dioxide emissions and employment and between economic growth and employment in the long run. There is a one-way long causality found flowing from electricity generated from renewables to economic growth without feedback. The Variance Decomposition approach suggested that electricity generation from renewables contributed positively to economic growth over time.

The foregoing posits that electricity generated from renewables is critical for the socio-economic development of the country. These results have important policy implication for a country like South Africa which has experienced power outages that crippled the important sectors of the economy such as the industrial and commercial sectors. South Africa is also considered one the highest greenhouse gas emitters. There was no causality found flowing from economic growth to electricity generated from renewables and this point to probable poor management of the electricity supply industry. Therefore, the government should make appropriate efforts to select energy policies that do not negatively affect economic growth.

REFERENCES

Al-mulali U., Fereidouni H., Lee J. & Che Sab B. 2013, Examining the bi-directional long run relationship between renewable energy consumption and GDP growth, *Renewable and Sustainable Energy Reviews*, 22(1), 209-222.

Bayraktutan Y., Yilgor M. & Ucak S. 2011, Renewable electricity generation and economic growth: Panel-data analysis for OECD members. *International Research Journal of Finance & Economics*, (66), 60-69.

Bento C. & Moutinho V. 2016, CO_2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy, *Renewable and Sustainable Energy Reviews*, 55(1), 142-155.

Cerdeira B. 2012, The role of foreign direct investment in the renewable electricity generation and economic growth nexus in Portugal: a Co-integration and causality analysis, *Munich Personal Re Pec Archive*, No. 41533:1-32.

Edkins M., Marquard A. & Winkler H. 2010, South Africa's renewable energy policy roadmaps. *Energy Research Centre*. Cape Town: University of Cape Town.

Greenpeace. 2011, The Eskom factor: Power politics and the electricity sector in South Africa. Johannesburg, South Africa.

Greenpeace. 2013, Powering the Future Renewable Energy Roll-out in South Africa. Renewable energy report. Johannesburg. South Africa.

Ghosh S. 2009, Electricity supply, employment and real GDP in India: Evidence from co-integration and granger-causality tests. *Energy Policy*, 37(8), 2926-2929.

Khide E. & Adjasi C, The causal relationship between renewable and non-renewable energy consumption and economic growth: The case of Nigeria. Paper presented at the Economic Society of South Africa at UCT on the 2nd – 4th September 2015.

Khobai H,. Abel S. & Le Roux. 2016, An investigation into the electricity supply and economic growth nexus for South Africa. *International Journal of Energy Economics and Policy*, 6(4), 701-705.

Lean H. & Smyth R. 2010, On the dynamics of aggregate output, electricity consumption and exports in Malaysia: Evidence from multivariate Granger-causality tests. *Journal of Applied Energy,* 87(6), 1963-1971.

Morimoto R. & Hope C. 2004, The impact of electricity supply on economic growth in Sri Lanka, *Journal of Energy Economics,* 26(1), 77-85.

Nnaji C., Chukwu J. & Nnaji M. 2013, Electricity supply, fossil fuel consumption, Co_2 emissions and economic growth: Implications and policy options for sustainable development in Nigeria, *International journal of Energy Economics and Policy*, 3(3), 262-271.

Ohler A. & Fetters I. 2014, The causal relationship between renewable electricity generation and GDP growth: A study of energy sources. *Energy Economics*. 43(1), 125-139.

Salim R., Hassan K. & Shafiei S. 2014, Renewable and non-renewable energy consumption and economic activities: Further evidence from OECD countries. *Energy Economics*. 44(1), 350-360.

Samuel U. & Lionel E. 2013, The dynamic analysis of electricity supply and economic development: Lessons from Nigeria. *Journal of Sustainable Society*, 2(1), 1-11.

Sarker, A.R. 2010. Nexus between electricity generation and economic growth in Bangladesh. *Asian social science,* 6(12), 16-22.

Yoo S. & Kim Y. 2006, Electricity generation and economic growth in Indonesia. *Energy,* 31(14), 2890-2899.

Phillips, P.C.B., Perron, P. (1988), Testing for unit roots in time series regression. Biometrika, 75, 335-346.
Said, S.E., Dickey, D. (1984), Testing for unit roots in autoregressive moving-average models with unknown order. Biometrika, 71, 599-607.