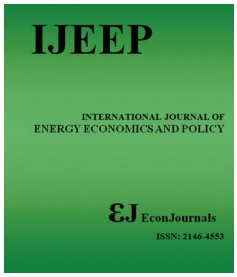

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# Renewable Energy Consumption, Poverty Alleviation and Economic Growth Nexus in South Africa: ARDL Bounds Test Approach

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**ABSTRACT**

This study examines the relationship between renewable energy consumption, poverty alleviation and economic growth in South Africa. The paper applies the autoregressive distributed lag (ARDL) model to examine the long run relationship and the Vector Error Correction Model (VECM) to determine the direction of causality between the variables. Quarterly data is used for the period 1990–2018. The findings of the paper established a presence of a long run relationship between renewable energy consumption, poverty, economic growth, financial development and government expenditure. Specifically, renewable energy consumption and economic growth have a negative and significant impact on poverty in both long run and short run. The VECM suggest that renewable energy consumption Granger-causes both economic growth and poverty in the long. Moreover, there is a bidirectional causality flowing between poverty and economic growth. The results have important implication for renewable energy policy makers as it can be realised that policies that promote adoption of clean technology will alleviate poverty in South Africa.

**Keywords:** Renewable Energy Consumption, Poverty Alleviation, Economic Growth, South Africa
**JEL Classifications:** C32, D04, Q47, Q42, Q01

## 1. INTRODUCTION

The second half of the twentieth century has witnessed the proliferation of a bourgeoning literature on the relationship between renewable energy consumption, poverty alleviation and economic growth. Despite the disagreements over the direction of causation, evidence suggests that renewable energy consumption enhances economic growth. There are four hypothesis associated with the direction of causality between energy consumption and economic growth. Growth, conservation, feedback and neutrality. The growth hypothesis argues that energy consumption is a major factor in boosting economic growth and validates a unidirectional causality flowing from energy consumption to economic growth. This means that a fall in energy consumption will negatively affect economic growth. The conservation hypothesis argues that there is a one-way causality flowing from economic growth to energy consumption and this implies that a reduction in energy consumption will not affect economic growth unfavorably. The feedback hypothesis validates that energy consumption and economic growth Granger-cause each other, that is, there is bidirectional causality running between energy consumption and economic growth. This implies that energy consumption supports economic growth and economic growth enhances energy consumption. The neutrality hypothesis contents that there is no causality flowing between economic growth and energy consumption. This means that a reduction in energy consumption has no adverse impact on economic growth.

Energy consumption and poverty reduction issues are related in numerous ways. Lak of access to sufficient and clean energy sources is detrimental to the living conditions of people, on their health as well as on their ability to engage in productive

activities. This can result in situations where people are trapped in poverty. It turns out that poverty has a bearing on the types of energy consumed, which in turn affects health, education and income earning opportunities. Therefore, giving people access to affordable and clean energy sources in an important lever of poverty reduction policies and available evidence shows that a significant proportion of the population in South Africa lack access even to the most basic energy supplies and services.

South Africa has seen a successful increase in the number of households with access to electricity by 8.2% between 2002 and 2012. However, within this backdrop, a very significant amount of households still remain without electricity or could not afford to use adequate electricity to satisfy their needs. Approximately, 60 percent of the rural households in South Africa have no access to electricity and more than 40 percent of the households that have access are considered energy poor, spending upward of 20 percent of their monthly income on power. Households without adequate access and or affordability of electrical energy often utilize multiple sources of energy such as wood and paraffin. These sources of energy increase the exposure of household members to health risks, such as indoor pollution, or ingestions of paraffin by infants and children as well as injury as a result of collecting these alternative sources over long distances and under hazardous conditions. Futhermore and importantly in densely populated shack settlements fire accidents caused by burning matter especially fluids such as paraffin are predominant citizens perennially lose their hard earned valuables especially in the winter months.

It cannot be disputed that energy plays an important role in the production of economic output and poverty alleviation. Therefore, this study analyses the relationship between renewable energy consumption, poverty alleviation and economic growth in South Africa using the ARDL bounds approach. The remainder of this paper is structured as follows: section 2 reviews the theoretical and empirical literature followed by section 3, which presents the model specification and data analysis techniques. Section 4 presents the findings of the research. The last section will give conclusions and policy recommendations

## 1.1. Overview of Poverty and Energy in South Africa

Lack of electricity and heavy reliance on traditional biomass are hallmarks of poverty in developing countries. Access to electricity and other modern energy sources is a necessary but not a sufficient, requirement for economic and social development. The escape from poverty also requires, among other things, clean water, adequate sanitation and health services, a good education system and communication network. Yet cheap and available energy is indispensable.

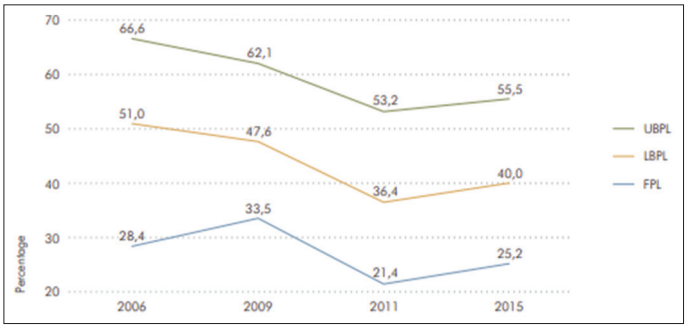
South Africa experienced power outages in 2008. Eskom's reserves were running lower than 8% in some areas and had to implement a blackout schedule – known as load shedding – to prevent crashing the entire national grid. Following these outages were high increases in the electricity prices which crippled the poor more. The companies experienced a massive loss on production while households lost on their leisure time. Eskom's solution to the problem was to encourage the local consumers to cut consumption by 20%. Realistically, the situation was expected to last until 2017, when Kusile and Medupi, the two coal power station being build in Mpumalanga and Limpopo respectively, bring an extra 4800MW each onto the grid.

While the impact of the 2008 electricity power outages is less apparent when measuring poverty using the UBPL, when examining poverty below the FPL it is clear that the crisis was particularly tough to those most deprived in South Africa (Figure 1). When applying the food poverty line (R441 per month in 2015 prices), it can be realised that the number of people living in poverty is extreme. Looking at the trend of the headcount in Figure 1, it can be realised that there is zig zag pattern, whereby poverty increased between 2006 and 2009, then took a deep in 2011 before rising again in 2015. Approximately, 13.8 million people in South Africa were living below the FPL in 2015, down from a peak of 16.7million in 2009. At the beak in 2009, roughly one in three people were food poor, with that proportion decreasing to one in four by 2015 (slightly lower than 2006 levels but still higher than the one in five experienced in 2011). The rapid movements upwards and downwards in the number of food-poor people illustrates the importance of food securing programmes and policies, especially when the country comes under increased pressure from climate change and water shortages.

The last 5 years, notably between 2011 and 2015, have been a rough economic rollercoaster for South Africa driven by a combination of international and domestic factors such as low and anemic economic growth, continuing unemployment and higher consumer prices (especially energy and food) and policy uncertainty. This period has seen the financial health of South African households decline under the weight of these economic pressures and in turn, pulled more households and individuals down into poverty.

Modern energy services enhance the life of the poor in countless ways. To mention a few: electricity light extends the day, providing extra hours for reading and work; modern cook-stoves save women and children from daily exposure to noxious cooking fumes and modern energy can directly reduce poverty by raising a poor country's productivity and extending the quality range of its products – thereby putting more wages into the pockets of the deprived.

**Figure 1:** Poverty headcounts based on the FBL, LBPL and UBPL (2006, 2009, 2011 and 2015)




Source: Statistics South Africa's report (2015)

## 2. LITERATURE

This section focuses on reviewing the literature on investigating the causal relationship between renewable energy consumption, poverty alleviation and economic growth applying 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 renewable energy consumption – economic growth nexus studies. The second category focuses on the studies that focused on renewable energy consumption and poverty alleviation. The last category concentrates on the studies done on economic growth and poverty alleviation.

### 2.1. Renewable Energy Consumption and Economic Growth

While the literature on energy consumption and economic growth has been extensively examined in the literature usually concentrating on energy consumption and/or electricity consumption variables, much fewer studies focused on the relationship between renewable energy consumption and economic growth. The purpose of this study is to extend research on the relationship between renewable energy consumption and economic growth. The studies undertaken to investigate these relationship established conflicting results. Amri (2017) established no long run relationship between renewable energy consumption and economic using the ARDL bounds testing approach for Algeria covering the period between 1980 and 2012. The causality results revealed a one way long run causality running from renewable energy consumption to economic growth. Amri (2017a) served to determine the relationship between economic growth, trade and renewable energy consumption for 72 countries (both developing and developed countries) for the period 1990–2012. The findings suggested bidirectional causality flowing between renewable energy consumption and economic growth.

One of the current studies was done by Ivanovski et al. (2021) aiming to determine the impact of renewable energy consumption and non-renewable energy consumption on economic growth for OECD and non-OECD countries covering the period between 1990 and 2015. The results from non-parametric model showed that both renewable and non-renewable energy consumption have a positive impact in non-OECD countries. Chen et al. (2020) focused 103 countries to investigate the relationship between renewable energy consumption and economic growth covering the period between 1995 and 2015. The findings showed that both developing and non-OECD countries portray a positive relationship between renewable energy consumption and economic growth upto a certain threshold.

Ozcan and Ozturk (2019) served to examine the relationship between renewable energy consumption and economic growth in17 emerging countries and only established a growth hypothesis for Poland and a neutral hypothesis for the remaining 16 emerging countries. Liu and Can and Korkmaz (2019) focused on Bulgaria to in investigating the relationship between renewable energy consumption and economic growth. The finding from the ARDL model showed no existence of a long run relationship but Toda-Yamamoto causality results posited that renewable energy consumption and renewable electricity output causes economic growth.

Omri et al. (2015) undertook a study investigate the relationship between energy consumption (nuclear and renewable energy) and economic growth in 17 countries divided between developing and developed countries for the period 1991–2011. The findings suggested that renewable energy consumption Granger-causes economic growth in Hungary, India, Japan, Netherlands and Sweden While in Argentina, Spain and Switzerland, economic growth Granger-causes renewable energy consumption. A feedback hypothesis was established for Belgium. Bulgaria, Canada, France and the USA. Finally, neutrality hypothesis was found in Brazil and Finland. In exploring West Africa, Maji and Sulaiman (2019) established that renewable energy consumption has an adverse effect on economic growth. This could be attributed to the fact that in West Africa, wood biomass is mostly used as the source of renewable energy.

Apergis and Payne (2014) aimed to investigate the relationship between output, renewable energy consumption, fossil fuel prices and carbon dioxide emissions for seven Central American countries covering the period 1980 – 2010. The study posited existence of a long run relationship between output, renewable energy consumption, fossil fuel prices and carbon dioxide emissions.

Sebri and Ben-Selha (2014) purposed to examine the relationship between economic growth, renewable energy consumption, trade openness and carbon dioxide emissions for the Brics (Brazil, Russia, India, China and South Africa) Countries for the period 1970–2010. The results from the ARDL bounds testing approach affirmed the presence of a long run relationship among the variables, while the VECM results indicated that renewable energy consumption and economic growth Granger-cause each other. Liang (2019) served to investigate the relationship between energy consumption, biodiversity and economic growth for China and five countries (Cambodia, Laos, Myanmar, Thailand and Vietnam). The ARDL model results posits that the fossil fuels have more effect on economic growth than renewable energy as such renewable energy is an alternative for fossil fuels.

Haseeb et al. (2019) contributed the most recent studies on renewable energy consumption – economic growth nexus. This Malaysian study revealed that renewable energy have a positive and significant effect on economic well-being both in the short and long run. Apergis and Payne (2011) investigated the relationship between economic growth and renewable energy consumption in six Central American countries for the period between 1980 and 2006. The findings from heterogeneous panel co-integration model confirmed the presence of a long run relationship between economic growth and renewable energy consumption, while the causality results established that renewable energy consumption and economic growth Granger-cause each other.

### 2.2. Economic Growth and Poverty Alleviation

There are two contentious views on the linkage between economic growth and poverty in the literature. The trickle-up theory states that economic growth does not improve the lives of the very poor but rather the growth process tend to trickle-up to the middle classes and the very rich. This in turn leads to the worsening of the distribution of income, which will increase poverty. On the otherhand, the trickle-down theory posits that economic growth plays a crucial role in poverty reduction provided that the distribution of income remains constant. The proponents of this theory believe that the benefits of higher economic growth in a country trickle down to the poor. As such, poverty reduction policies should aim at boosting economic growth (Todaro 1997)

The relationship between poverty and economic growth can be many fold (Hichem, 2016):

- Economic growth is considered an important and necessary condition, but sufficient because of the effects of inequality
- A high pace of growth is very necessary to alleviating poverty over the extended period
- Poverty alleviation from high growth rates can be realised only when the sources of growth are expanding
- The effects of growth to poverty vary across countries because of many factors such as distribution, depth of poverty, poverty characteristics etc.

Hichem (2016) undertook a study to investigate the relationship between poverty, inequality and growth in Algeria covering the period between 1970 and 2013. Using the ARDL bounds test approach, the study established that there is a long run relationship between economic growth, poverty and inequality. The link is such that increasing economic growth leads to a fall in poverty.

Chani et al. (2011) examined the link between poverty, inflation and economic growth in Pakistan for the period 1972–2008. The study included investment and trade openness as the additional variables. The results from the ARDL bounds test suggested that there is a long run relationship among the variables. The short run results posited that economic growth has a positive effect on poverty.

Nindi and Odhiambo (2015) investigated the causal relationship between poverty reduction and economic growth in Swaziland covering the period between 1980 and 2011. The study employed the ARDL bounds test approach to co-integration to analyse the long run relationship among the variables and the ECM-based Granger causality method to determine the direction of direction of causality among the variables. The findings suggest that economic growth does not Granger-cause poverty reduction both in the long and short run. Whereas, causality flowing from poverty reduction to economic growth is established in the short run.

Odhiambo (2011) examined the relationship between economic growth, unemployment and poverty reduction in South Africa covering the period between 1969 and 2006. The findings from the ARDL bounds test approach indicated there is no causality flowing between economic growth and poverty in South Africa. Another South African study was done by Odhiambo (2009), which purposed to investigate the causal relationship between financial development, economic growth and poverty reduction covering the period between 1960 and 2006. The findings revealed a one-way causality flowing from economic growth to poverty reduction.

## 3. METHODOLOGY

### 3.1. Data Collection

The main aim of this research is to ascertain whether energy consumption and economic growth alleviate poverty in South Africa. This study utilises quarterly time series data covering the period of 1990–2018. In order to empirically analyse the link between energy consumption, economic growth and poverty alleviation, the study incorporate inequality as an intermittent variable to form a multivariate framework. The variables used in the study are measured as follows: Economic growth is measured as Gross domestic production (GDP) per capita at 2010 constant prices; Due to lack of time series data on poverty in many developing countries, many proxies have been used for poverty. These include such as headcount data for the poor, Gini coefficient, infant mortality and life expectancy. Following from Nyasha et al. (2016) and Odhimabo (2011), our study adopts infant mortality rate as a proxy for poverty; Renewable is measured a percentage of total final energy consumption; Financial development is domestic credit extension to private sector by financial intermediaries (a proxy for bank-based financial development); Government is a measured general governmental final consumption expenditure. Data on economic growth, financial development, poverty, government expenditure was extracted from the World Development Indicators (WDI) published by the World Bank (WB 2016) while data for renewable energy consumption was sourced from International Energy Agency (IEA).

### 3.2. Model Specification

The model specification to explore the causal linkage between energy consumption, poverty alleviation, economic growth and inequality is based on a simple multivariate framework where the link is represented as follows:

$$LPOV_t=\alpha+\beta_1 LRE_t+\beta_2 LGDP_t+\beta_3 LFD_t+\beta_4 LGE_t+\mu_t \quad (1)$$

Where: LPOV represents the log of poverty alleviation (measured by infant mortality rate), LRE is the log of renewable energy consumption, LGDP denotes the log of gross domestic product per capita (a proxy for economic growth), LFD is the log of financial development and GE is the log of government expenditure. 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*

Prior to conducting the bounds test for cointegration, the study applies the unit root test to ensure that none of the variables are

integrated of order *I*(2). This is on account that the F-test would be spurious if the variables are stationary at second difference. To test for stationarity of the variables, this study applies the Augmented Dickey Fuller (ADF) by Said and Dickey (1984), Phillips and Perron (PP) by y Phillips and Perron (1988) and Dickey-Fuller Generalised Least Squares (DF-GLS) unit root tests by Elliott, Rothenberg and Stock (1992). The DF-GSL unit root test is chosen for its power over the other procedures. It also helps remove the means and linear trends for series that are not far from the non-stationarity region. After knowing the stationarity level or order of integration of different time series involved, co-integration between the variables can be conducted.

### *3.2.2. Co-integration*

After confirming the order of integration of the variables, the next step is determine the presence of a long run relationship between energy consumption, poverty alleviation, economic growth and inequality. The first version of the cointegration test was proposed by Engle and Granger (1987) and was based on the estimated residuals of a long run regression model. Therefore, this model was named the residual based test of cointegration. A decade later, various other cointegration techniques were developed such as the ECM-based t-test of Banerjee et al. (1998), the ECM-based F-test of Boswijk (1994) and the system-based test of Johansen (1988). Unfortunately, different outcomes were found from different cointegration techniques and this suggests that no one cointegration test was perfect and completely robust in all applications. To improve the power of the cointegration techniques the study employs the autoregressive distributed lag (ARDL) bounds test approach.

The ARDL approach was chosen to determine the long run relationship between energy consumption, poverty alleviation, economic growth and inequality for the following reasons; It is very efficient with small sample sizes, it is valid irrespective of whether the variables are integrated of order I(0) or I(1) or both and it corrects the omitted lagged variables bias. The dynamic unrestricted error correction models (UECM) are expressed in the following equations;

$$\Delta lnPOV_t = \alpha_1 + \alpha_T T + \alpha_{POV} lnPOV_{t-1} + \alpha_{RE} lnRE_{t-1} + \alpha_{FD} lnFD_{t-1} + \alpha_{GE} lnGE_{t-1} + \alpha_{GDP} lnGDP_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta lnPOV_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta lnRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta lnFD_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta lnGE_{t-l} + \sum_{l=0}^{v} \alpha_l \Delta lnGDP_{t-l} + \varepsilon_{1t} \quad (2)$$

$$\Delta lnRE_t = \alpha_1 + \alpha_T T + \alpha_{POV} lnPOV_{t-1} + \alpha_{RE} lnRE_{t-1} + \alpha_{FD} lnIFD_{t-1} + \alpha_{GE} lnIGE_{t-1} + \alpha_{GDP} lnGDP_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta lnPOV_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta lnRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta lnIFD_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta lnGDP_{t-l} + \sum_{m=0}^{v} \alpha_m \Delta lnGE_{t-m} + \varepsilon_{2t} \quad (3)$$

$$\Delta \ln IFD_t = \alpha_1 + \alpha_T T + \alpha_{POV} lnPOV_{t-1} + \alpha_{RE} lnRE_{t-1} + \alpha_{FD} lnFD_{t-1} + \alpha_{GDP} lnGDP_{t-1} + \alpha_{GE} lnIGE_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta lnPOV_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta lnRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta lnFD_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta lnGDP_{t-l} + \sum_{m=0}^{v} \alpha_m \Delta lnGE_{t-m} + \varepsilon_{4t} \quad (4)$$

$$\Delta lnGDP_t = \alpha_1 + \alpha_T T + \alpha_{POV} lnPOV_{t-1} + \alpha_{RE} lnRE_{t-1} + \alpha_{FD} lnFD_{t-1} + \alpha_{GDP} lnGDP_{t-1} + \alpha_{GE} lnIGE_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta lnPOV_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta lnRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta lnFD_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta lnGDP_{t-l} + \sum_{m=0}^{v} \alpha_m \Delta lnGE_{t-m} + \varepsilon_{4t} \quad (5)$$

$$\Delta lnGE_t = \alpha_1 + \alpha_T T + \alpha_{POV} lnPOV_{t-1} + \alpha_{RE} lnRE_{t-1} + \alpha_{FD} lnFD_{t-1} + \alpha_{GDP} lnGDP_{t-1} + \alpha_{GE} lnIGE_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta lnPOV_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta lnRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta lnFD_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta lnGDP_{t-l} + \sum_{m=0}^{v} \alpha_m \Delta lnGE_{t-m} + \varepsilon_{5t} \quad (6)$$

Where: $LPOV_t$ is the natural logarithm of poverty reduction; $LRE_t$ is the natural logarithm of energy consumption; $LGDP_t$ is the natural logarithm of Gross Domestic Product; $LFD_t$ is the natural logarithm of financial development; $LGE_t$ is the natural logarithm of government expenditure. T and Δ represent the time period and the first difference operator, respectively. It is assumed that the residuals ($\varepsilon_{1t,}$ $\varepsilon_{2t,}$ $\varepsilon_{3t,}$ $\varepsilon_{4t}$) are normally distributed and white noise.

The existence of a long run relationship between the variables is determined based on an F-test (Wald test) by setting the coefficients of one period lagged level of the independent variables equal to zero. The null hypothesis of no co-integration among the variables is $H_0$: $\alpha_{POV} = \alpha_{RE} = \alpha_{FD} = \alpha_{GDP=} \alpha_{GE} = 0$ tested against the alternative hypothesis $H_1$: $\alpha_{POV} \neq \alpha_{RE} \neq \alpha_{FD} \neq \alpha_{GDP} \neq \alpha_{GE} \neq 0$. In order to reject or accept the null hypothesis, the value of the F-test is compared with critical value bounds. The lower bound values are computed based on the assumption that all of the variables in the regression equation are I(0), while upper critical bound values are computed based on the assumption that all of the variables in the regression equation are I(1). Therefore, the two sets of critical values provide critical value bounds for all classification of the repressors into purely I(0), purely, I(1) or mutually co-integrated.

As a result, if the calculated F-statistics exceeds the upper critical bound value, then the $H_0$ is rejected and the results conclude in favour of co-integration. On the contrary, $H_0$ cannot be rejected if the F-statistics falls below the lower critical bound value. Finally, if the F-statistics falls within the two bounds, then the co-integration test becomes inconclusive.

If a long run relationship between the variables is established, the next step is to investigate the long run and short run relationship among variables of interest. To estimate the long run relationship among the variables based on the ARDL approach, the following equation is built up.

$$LPOV_t = \alpha_1 + \sum_{i-1}^{P} \phi_t LPOV_{t-1} + \sum_{i=0}^{q} \lambda_i LRE_{t-i} + \sum_{i=0}^{r} \eta_i LFD_{t-i} + \sum_{t-0}^{s} \vartheta_i LGDP_{t-i} + \sum_{i=0}^{v} \rho_i LGE_{t-i} + \mu_t \quad (7)$$

Furthermore, in order to investigate the short run dynamics from the ARDL model and recheck the presence of co-integration established in the ARDL model, the study estimates the error correction model, which is developed as follows:

$$LPOV_t = \alpha_1 + \sum_{i-1}^{P} \phi_t LPOV_{t-1} + \sum_{i=0}^{q} \lambda_i LRE_{t-i} + \sum_{i=0}^{r} \eta_i LFD_{t-i} + \sum_{t-0}^{s} \vartheta_i LGDP_{t-i} + \sum_{i=0}^{v} \rho_i LGE_{t-i} + \Psi ECM_{t-1} + \mu_t \quad (8)$$

If the coefficient of the ECM in the equation is negative and significant, there is an existence of a long run relationship among the variables. This also denotes the speed of adjustment to the equilibrium.

Finally, to determine the reliability of the ARDL result, the study checks for serial correlation, functional form, normality and heterosckedasticity of the ARDL model. In addition, the stability of the parameters will be tested using the Cumulative Sum of Recursive Residual (CUSUM).

### *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. (9) – Eq. (13). In each equation, the dependent variable is explained by itself, the independent variables and the error correction term.

$$\Delta LPOV_t = \alpha_{10} + \sum_{i=1}^{p} \alpha_{11}\Delta LPOV_{t-i} + \sum_{i-1}^{q} \alpha_{12}\Delta LRE_{t-i} + \sum_{i-1}^{r} \alpha_{13}\Delta LFD_{t-i} + \sum_{i-1}^{s} \alpha_{14}\Delta LGDP_{t-i} + \sum_{i=1}^{v} \alpha_{15}\Delta LGE_{t-i} + \Psi_1 ECT_{t-i} + \varepsilon_{1t} \quad (9)$$

$$\Delta LRE_t = \alpha_{20} + \sum_{i=1}^{q} \alpha_{21}\Delta LRE_{t-i} + \sum_{i-1}^{r} \alpha_{22}\Delta LPOV_{t-i} + \sum_{i-1}^{s} \alpha_{23}\Delta LFD_{t-i} + \sum_{i-1}^{t} \alpha_{24}\Delta LGDP_{t-i} + \sum_{i=1}^{v} \alpha_{25}\Delta LGE_{t-i} + \Psi_2 ECT_{t-i} + \varepsilon_{2t} \quad (10)$$

$$\Delta LFD_t = \alpha_{30} + \sum_{i=1}^{q} \alpha_{31}\Delta LFD_{t-i} + \sum_{i-1}^{r} \alpha_{32}\Delta LRE_{t-i} + \sum_{i-1}^{s} \alpha_{33}\Delta LPOV_{t-i} + \sum_{i-1}^{t} \alpha_{34}\Delta LGDP_{t-i} + \sum_{i=1}^{v} \alpha_{35}\Delta LGE_{t-i} + \Psi_3 ECT_{t-i} + \varepsilon_{3t} \quad (11)$$

$$\Delta LGDP_t = \alpha_{40} + \sum_{i=1}^{q} \alpha_{41}\Delta LGDP_{t-i} + \sum_{i-1}^{r} \alpha_{42}\Delta LRE_{t-i} + \sum_{i-1}^{s} \alpha_{43}\Delta LFD_{t-i} + \sum_{i-1}^{t} \alpha_{44}\Delta LPOV_{t-i} + \sum_{i=1}^{v} \alpha_{45}\Delta LGE_{t-i} + \Psi_4 ECT_{t-i} + \varepsilon_{4t} \quad (12)$$

$$\Delta LGE_t = \alpha_{50} + \sum_{i=1}^{q} \alpha_{51}\Delta LGDP_{t-i} + \sum_{i-1}^{r} \alpha_{52}\Delta LRE_{t-i} + \sum_{i-1}^{s} \alpha_{53}\Delta LFD_{t-i} + \sum_{i-1}^{t} \alpha_{54}\Delta LPOV_{t-i} + \sum_{i=1}^{v} \alpha_{55}\Delta LGE_{t-i} + \Psi_5 ECT_{t-i} + \varepsilon_{5t} \quad (13)$$

$\Delta$ represent the difference operator, $\alpha_{it}$ 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

It is important to pre-test the variables for stationarity because the tests provide guidance as to whether ARDL bounds test should be applied or not as the approach in only appropriate for the analysis of variables that are integrated of order not more than one I(1). 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. The results are reported in Table 1 and show that the variables (economic growth, poverty alleviation, renewable energy consumption and government spending) are non-stationary at levels under both the ADF and PP unit roots tests. The results further reveal that all the variables become stationary differenced once rejecting the null hypothesis at 5 percent level of significance under both PP and ADF. Generally, the results show that all the variables are stationary at first difference except for financial development, which is stationary at levels.

### 4.2. Co-integration

Since the variables are found to be integrated of both order I(0) and I(1), the ARDL bound test approach is applied to analyse the long run relationship among the variables. 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 2. Table 2 reports that the optimal lag length P*=1 is chosen.

**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 |
| LPOV | –0.38 | –4.36* | –3.20 | –4.07* | 0.06 | –2.67* | –2.90 | –2.28** |
| LENG | –1.68 | –3.83* | –2.56 | –3.67* | –1.98 | –3.81* | –2.78 | –3.63* |
| LFD | –2.82* | –4.64* | –3.10* | –4.82* | –2.89* | –4.64* | –3.09* | –4.91* |
| LGDP | –0.72 | –2.87* | –2.88 | –2.56** | 0.15 | –2.78* | –3.42* | –2.26** |
| LGE | –0.93 | –3.98* | –3.08 | –4.02** | 0.76 | –3.01** | –1.69 | 3.82** |

Source: Own calculation

**Table 2: Selection order criteria**

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 316.0531 | NA | 3.80e-18 | –25.92109 | –25.67567 | –25.85598 |
| 1 | 416.5009 | 150.6716* | 7.47e-21* | –32.20841* | –30.7358* | –31.8177* |
| 2 | 439.7654 | 25.20327 | 1.18e-20 | –32.06379 | –29.36408 | –31.34755 |

Source: Own calculation

After getting assured about the order of integration, the next step is to move towards determining the co-integrating linkages between the variables. Table 3 shows the estimates for ARDL bound testing approach testing approach. The calculated F-statistics is 7.77 when poverty is used as the dependent variable and is greater than the upper critical bounds generated by Pesaran et al. (2001). The F-statistics for economic growth (13.77), renewable energy consumption (8.31), financial development (14.04) and government expenditure (7.68) are also greater than the critical bounds when each are taken as the dependent at 1% level of significance. This implies that there is presence cointegration among poverty, economic growth, renewable energy consumption, financial development and government expenditure.

Table 4 reports the partial effects of independent variables on poverty in a long run. Renewable energy consumption, economic growth and financial development are negatively related to poverty and significant at 5% except for financial development, which is insignificant. Specifically, a 1% increase in renewable energy consumption leads to 4.46% decrease in poverty ceteris paribus. Renewable energy is important for environmental sustainability and saves people from air pollution and water pollution. This will save their health and hence the little income that the people have will be invested in productive activities instead of spending on health. Furthermore, all else held constant, a 1% point increase in economic growth reduces poverty by 9.8%. The relationship between government expenditure and poverty are found to be positive but insignificant.

Table 5 reports that short run results portray the similar relationship among the variables as shown by the long run. The findings indicate that the relationship between renewable energy consumption and poverty is negative and significant at 1% level of significance. Specifically, a 1% increase in renewable energy consumption reduces poverty by 0.9%, ceteris paribus. Financial development and economic growth also negatively affect poverty and are significant at 5% level of significance. All else the same, a 1% increase financial development leads a 0.2% fall in poverty. Moreover, a 1% percentage point increase in economic growth alleviates poverty by 0.5%, all else held constant. Government expenditure has a positive but insignificant effect on poverty.

**Table 3: Autoregressive distributed lag (ARDL) results**

| Critical value bound of the F-statistic | | | | | | |
|---|---|---|---|---|---|---|
| K | 90% level | | 95% level | | 99% level | |
| | I(0) | I(1) | I(0) | I(1) | I(0) | I(1) |
| 3 | 2.022 | 3.112 | 2.459 | 3.625 | 3.372 | 4.797 |
| 4 | 1.919 | 3.016 | 2.282 | 3.340 | 3.061 | 4.486 |
| Calculated F-statistics | | | | | | |
| $F_{POV}$(POV/RE, FD, GDP, GE) = 7.77 | | | | | | |
| $F_{RE}$(RE/POV, FD, GDP, GE) = 8.31 | | | | | | |
| $F_{FD}$(FD/POV, RE,GDP, GE) = 14.04 | | | | | | |
| $F_{GDP}$(GDP/POV, RE, FD, GE) = 13.77 | | | | | | |
| $F_{GE}$(GE/POV, RE, FD, GDP) = 7.68 | | | | | | |

Source: Own Calculation. The critical bound values were taken from Narayan and Smyth (2005: 470).

**Table 4: Long run results**

| Dependent variable = LPOV | | | |
|---|---|---|---|
| Long term results | | | |
| Variable | Coefficients | Standard error | T-statistics |
| Constant | 1.342 | 4.8152 | 0.2788 |
| LRE | –4.459** | 1.6422 | –2.2722 |
| LFD | –2.4877 | 0.7649 | –3.2523 |
| LGDP | –0.0986** | 0.0204 | –4.8261 |
| LGE | 0.1862 | 0.4112 | 0.4528 |
| R-squared 0.99 | | | |
| Durbin Watson Stat 2.85 | | | |

Source: Own calculations

The coefficient of $ECM_{t-1}$ shows speed of adjustment from short run to long run equilibrium and it should have a negative sign and be statistically significant. Table 5 posits the error term (–0.2238) is negative and significant at 1% level of significance and suggests that estimated long run relationship is stable. This means that any deviation in the short run from the long run equilibrium in our poverty model is corrected by 22.38% percent per year.

The diagnostic tests results are displayed in Table 6. It was confirmed that the error terms of the short run models are free of

heteroskedasticity, have no serial correlation and are normally distributed. It was also established that the Durbin Watson statistics is greater than the $R^2$, which means that the short run models are not spurious.

Cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ), proposed by Brown, Durbin and Evans (1975). The CUSUM test uses the cumulative sum of recursive residuals based on the first set of observations and is updated recursively and plotted against break points. If the plot of CUSUM statistics stays within the critical bounds of 5 percent significance level (represented by a pair of red straight lines drawn at the 5 percent level of significance), the null hypothesis that all coefficients in the error correction model are stable cannot be rejected. If either of the lines is crossed, the null hypothesis of coefficient constancy can be rejected at the 5 percent level of significance Brown et al. (1975). A similar procedure is used to carry out the CUSUMSQ test, which is based on the squared recursive residuals. Based on the result obtained as indicated in Figures 2 and 3 we fail to reject the null hypothesis of perfect parameter stability.

## 4.3. Stability Tests

The diagnostic tests results are displayed in Table 6. It was confirmed that the error terms of the short run models are free of heteroskedasticity, have no serial correlation and are normally distributed. It was also established that the Durbin Watson statistics is greater than the R2, which means that the short run models are not spurious.

**Table 5: Short run analysis**

| Variable | Coefficient | Standard error | T-statistics |
|---|---|---|---|
| LRE | –0.9084* | 0.2491 | –3.6466 |
| LFD | –0.2486** | 0.0746 | –3.3304 |
| LGDP | –0.0049** | 0.0019 | –2.5565 |
| LGE | 0.0298 | 0.1915 | 0.1554 |
| $ECM_{t-1}$ | –0.2238* | 0.0279 | –8.0327 |
| $R^2$ | 0.99 | | |
| D.W test | 2.05 | | |

Source: Own calculation. *Represent 1%, significance level

**Table 6: Short-run diagnostics**

| Short run diagnostics | | |
|---|---|---|
| **Test** | **F-statistics** | **P-value** |
| Normality | 0.3221 | 0.8513 |
| Heteroskedasticity | 0.1715 | 0.6829 |
| Serial correlation | 0.8155 | 0.4638 |

Source: Own calculation

**Table 7: Granger-causality**

| Dependent variable | Types of causality | | | | | |
|---|---|---|---|---|---|---|
| | Short run | | | | | Long run |
| | ∑ΔLpov | ∑ Δlre | ∑ Δlgdp | ∑ Δlfd | ∑ Δlge | $ECT_{t-1}$ |
| ΔLpov | …….. | 1.76 | 0.08 | 0.99 | 2.07 | –0.034** |
| Δlre | 1.40 | ……. | 3.84** | 4.44** | 0.12 | –0.16 |
| Δlgdp | 1.00 | 8.38* | …….. | 9.96* | 3.09** | –1.81** |
| Δlfd | 1.11 | 1.24 | 0.97 | …….. | 0.009 | 0.09 |
| Δlge | 0.09 | 0.35 | 0.67 | 0.34 | ……. | –0.03 |

Source: Own calculation

## 4.4. Granger-causality

The direction of causal relationship is investigated using the VECM Granger-causality presented in Eq. (9) – Eq. (13) and the findings are represented in Table 7. In model 1, where poverty is the dependent variable, the coefficient of the error correction term is found to be negative and significant at 5 percent level of significance. This implies that there is a unidirectional causality flowing from renewable energy consumption, economic growth, financial development and government expenditure to poverty in the long run. The results further shows that there is a unidirectional causality running from poverty, renewable energy consumption, financial development and government expenditure. This is because when economic growth is the dependent variable, the coefficient of the error correction term is found to be negative and significant at 5 percent level of significance.

The results of the Wald test suggest there is the following short run causalities: (i) There is bidirectional causality running between economic growth and renewable energy consumption; (ii) there is a one way causality flowing from financial development to renewable energy consumption; (iii) there is a unidirectional causality flowing from financial development to economic growth; (iv) there is a unidirectional causality running from government expenditure to economic growth.

**Figure 2:** CUSUM

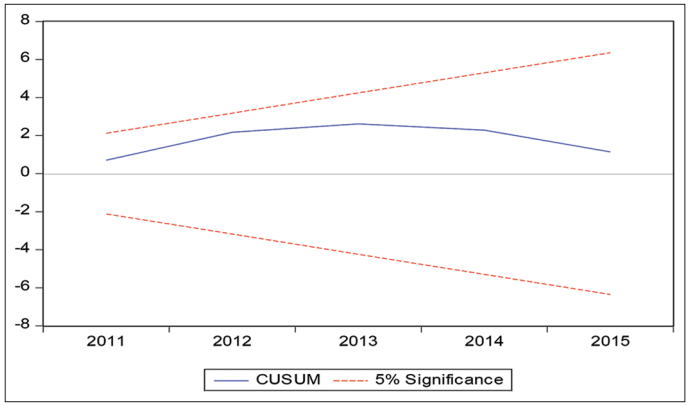



**Figure 3:** CUSUMsq

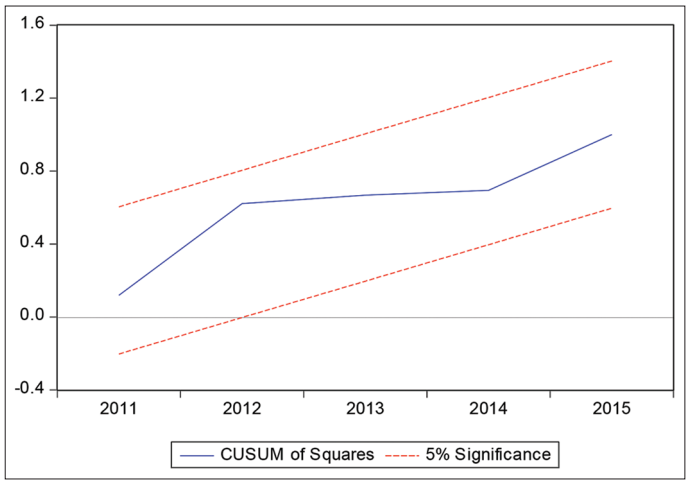
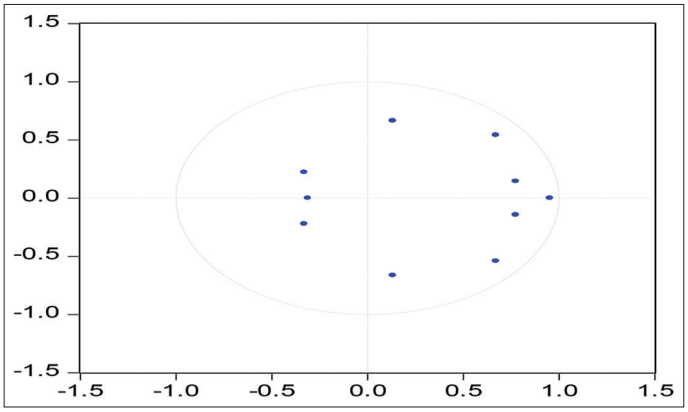


**Figure 4:** Inverse Roots of AR characteristic polynomial




### 4.5. Stability Test

The VECM model was tested for its stability and stationarity using Inverse Roots of AR characteristics Polynomials (Figure 4). 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.

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.

## 6. CONCLUSION

Clean energy is a driver for development and growth in developing countries. The main objective of this was to determine the relationship between renewable energy consumption, poverty alleviation and economic growth in South Africa covering the period between 1990 and 2016. The study incorporated government expenditure and financial development as intermittent variables. The ARDL bounds test approach was used to determine the long run relationship among the variables and the VECM was applied to examine the direction of causality between the variables.

The results from the ARDL model indicated that there is a long run relationship between renewable energy consumption, economic growth, poverty alleviation, government expenditure and financial development in South Africa. More specifically, the renewable energy consumption and economic growth have a negative effect on poverty both in the long run and short run. The VECM results posited that there is a bidirectional causality flowing between poverty and economic growth. Furthermore, it was discovered that renewable energy consumption Granger-causes both economic growth and poverty. This implies that poverty and economic growth depends on renewable energy consumption.

The results confirm that the installation of renewable energy systems in South Africa will help alleviate poverty which is one of the three challenges faced in the country. It has also been established that renewable energy boosts economic growth. It is of utmost importance that the government and renewable energy policy makers should support the usage of renewable energy technologies in South Africa and curb the long run environmental degradation associated with carbon emissions.

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