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# Renewable energy consumption and unemployment in South Africa

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## Abstract

The importance of renewable energy consumption has grown to a large extent over the recent years. The benefits of renewable energy consumption ranging from improved environmental quality to higher economic growth are well documented. However, the impact of renewable energy consumption on unemployment has received relatively less attention. This study examines the relationship between renewable energy consumption and unemployment in South Africa over the period 1990-2014. The Autoregressive Distributed Lag (ARDL) model was employed to test the long-run and short-run impacts of renewable energy consumption on unemployment. The results reveal that renewable energy consumption has a negative and significant effect on unemployment in the long-run. However, in the short-run the variables have an insignificant relationship. The study therefore advocates for an increase in the production and consumption of renewable energy in order to boost employment levels.

JEL Classification: Q20; C50

**Keywords:** Renewable energy consumption, unemployment, ARDL, South Africa

## 1 Introduction

The importance of renewable energy consumption has grown to a large extent over the recent years. The benefits of renewable energy consumption ranging from improved environmental quality to higher economic growth are well documented literature (see Kahia, Aissa & Charfeddine, 2016, Salim, Hassan & Shafiei, 2014. Ibrahiem, 2015, Khobai & Le Roux, 2017, Sebri & Ben-Salha, 2014 and Apergis & Danuletiu, 2014). Renewable energy can offer solutions for the dual objective of ensuring growth and the imperative to decarbonise economies across the globe (IRENA, 2016). Since the renewable energy is part of the sustainable development goal, it plays a vital role in creating jobs, improving the wellbeing of the society. However, the impact of renewable energy consumption on unemployment has received relatively less attention. Renewable energy technologies including solar, wind and hydro power are more labour intensive compared to the non-renewable energy sources and may boost employment levels worldwide (IRENA, 2011). Potential jobs from renewable energy technologies include those in processing raw materials, manufacturing technologies and plant construction.

The importance of renewable energy in South Africa can be traced to the constitution of 1996 which dictates that a sustainable energy future is a requirement for country in order to preserve the right of every individual to an environment that is not harmful to their health or well-being (Department of Energy, 2015). Furthermore, preventing pollution and ecological degradation is necessary for securing sustainable development. Three policy documents namely the White Paper on Energy Policy of 1998, the Renewable Energy White Paper of 2003 and the National Climate Change Response Policy White Paper of 2011 have been created since the adoption of the constitution (Department of Energy, 2015).

This study examines the relationship between renewable energy consumption and unemployment in South Africa over the period 1990-2014. All the data is sourced from the World Bank's World Development Indicators. South Africa is selected for the following reasons. Firstly, the unemployment rate has been high and has continued to increase over the recent years. Furthermore, for the period of the study unemployment averages just below 24% and currently stands over 25% (World Bank, 2017). The high unemployment rate has had a negative impact on economic growth and living standards. Secondly, there is scant evidence on the impact of renewable energy on unemployment in South Africa and this study seeks to bridge that gap. Lastly, South Africa has the one of the highest carbon emission in the world

which can be reduced by the growth in renewable energy consumption relative to renewable energy consumption.

The Autoregressive Distributed Lag (ARDL) model proposed by Pesaran, Shin and Smith (2001) is employed to test the long-run and short-run impact of renewable energy consumption on unemployment. The remainder of the study is structured as follows: section two provides an overview of renewable energy in South Africa, section surveys the literature on renewable energy and unemployment, section four discusses the data, methodology and results and section five concludes the study.

## **2 Overview of renewable energy in South Africa**

Various sources of renewable energy available in South Africa include solar, wind and biofuels. The country has one of the highest solar resources in the world (Edkins, Manquard & Winkler, 2010). The annual 24-hour global solar radiation average is about 220 W/m<sup>2</sup> for South Africa, compared with about 150 W/m<sup>2</sup> for parts of the USA, and about 100 W/m<sup>2</sup> for Europe and the United Kingdom. Most areas in South Africa average more than 2 500 hours of sunshine per year, and average solar-radiation levels range between 4.5 and 6.5kWh/m<sup>2</sup> in one day.

South Africa has fair wind potential, especially along the coastal areas of Western and Eastern Cape. Biofuels are another source of renewable energy. The South African Cabinet approved the National Biofuels Industrial Strategy in 2007 which sort a 2% biofuels penetration to the current fuel pool by 2013. The 2% penetration was purported to contribute to energy security, create 25 000 jobs in rural farming, and achieve a balance of payments saving of R1.7 billion. There is the possibility of hybrid energy systems which are a combination of two or more renewable energy sources such as PV (photovoltaic), wind, micro-hydro, storage batteries and fuel powered Gen-sets to provide a reliable off-grid supply. Currently, there are two pilot hybrid systems in the Eastern Cape in South Africa at the Hluleka nature reserve on the Wild Coast and at the neighbouring Lucingweni community. The Hluleka hybrid mini-grid system consists of two proven 2.5 kW wind generators and three Shell Solar PV module arrays fitted with 56 100-watt PV modules wired in series (total 10.6kW). The Lucingweni hybrid system consists of 50kW solar PV panels and 36kW wind generators serving 220 dwellings (four lights per dwelling, radio, television, cell phone charger, street lighting, telecommunications and water pumping).

The White Paper on Energy Policy of 1998 was the first policy document on energy and recognised the need for affordable energy services for the country's citizens in order to reduce

the inequalities in the access and usage of energy (Department of Minerals and Energy, 1998). The objectives of the White Paper also included managing the effect of energy sources on the environment, improving energy governance and promoting economic development. However, in 1998 the country was focused on utilising the vast amount of coal reserves available to generate electricity at the lowest cost possible and therefore coal remained the country's primary energy source. Due to the large coal reserves, the country had an oversupply of electricity and the reserve margin close to 25% in 1998 which enabled the Eskom and the government to fast track their electrification programme to households who previously had no access to electricity (Department of Energy, 2015). In 1998 renewable energy played a minimal role in global electricity generation, however, the White Paper recognised that the growth of renewable energy was vital in ensuring that the goal of cost-effective energy production was realised.

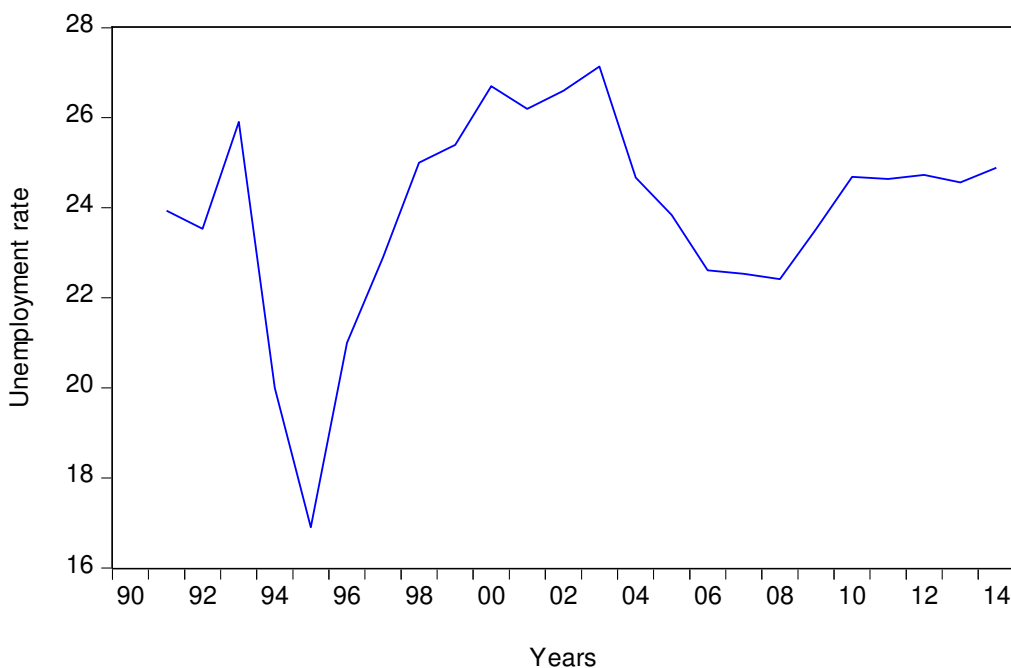
The Renewable Energy White Paper of 2003 states that the White Paper on energy policy mentioned renewable energy briefly and did not provide an actual target for renewable energy (Department of Energy, 2015). The objectives of the Renewable Energy White Paper included ensuring that a reasonable amount of natural resources was invested in renewable energy technologies, creating a favourable investment climate for foreign and domestic investors to invest in renewable energy and to develop a legal framework for pricing and tariff structure to enable the integration of renewable energy into the energy economy (Department of Minerals and Energy, 2003). Furthermore, the policy also sort to encourage the use of renewable energy by making the public more aware of it.

The Department of Environmental Affairs (DEA) National Climate Change response policy White Paper of 2011 was third noteworthy policy paper that promoted renewable energy consumption (Department of Energy, 2015). The policy came about as a result of a process known as Long-term Mitigation Scenario (LTMs) which sort to reduce the country's carbon emissions. The LTMs recognised that despite the extensive reliance of the country on coal for electricity, use of renewable energy was vital for a clean environment. Furthermore, in 2011 the Renewable Energy Independent Power Producer Procurement Program (REIPPPP) was implemented (Sager, 2014). The program is a competitive tender operation which allows investments by the private sector to the grid-connected renewable energy. In 2014 over 64 projects were awarded to the private sector and investments totalled US\$64 generating 3922 megawatts of renewable energy (Eberhand, Kolker, & Leigland, 2014).

## 2.1 Trends in unemployment and renewable energy

This section outlines the trends in unemployment and renewable energy consumption as a percentage of GDP in South Africa for the time period under consideration in the study. Figure 1 shows the trends in the unemployment rate for the period 1990 to 2014. Mainly because of the end of apartheid era and removal of heavy sanctions on South African people, unemployment diminished drastically from 27% to 17% in 1995. The removal of sanctions boosted exports which in turn resulted in higher employment levels. The period between 1996 and 2003 saw an upward trend in unemployment. The increase resulted partly from the drought experienced around 1995 and the Asian financial crises of 1997/1998 which caused a decline in exports of goods and services from South Africa. During the period 2004 to 2007 South Africa's economic growth rate averaged over 5% which was responsible for the decline in the unemployment rate. The global financial and economic crises of 2008-09 resulted in an economic downturn due to many external factors such as a drop in exports of goods and service and FDI inflows. As such, the unemployment rate increased during the years of the global financial crises and due to the modest recovery of the South African economy from the crisis, this upward trend has continued.

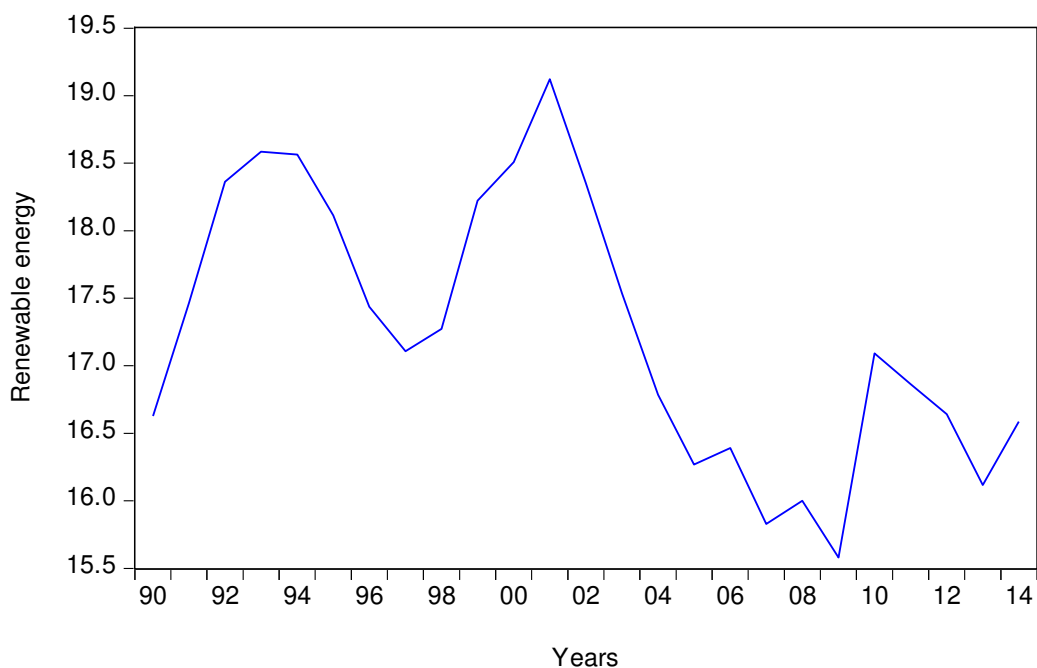
**Figure 1: Trends in the unemployment rate from 1990-2014**



**Source: World Bank (2017)**

Figure 2 outlines the trend in renewable energy consumption. Renewable consumption has fluctuated to a large extent over the period of the study. The variable showed an increasing trend in the early 1990s before declining between 1994 and 1997. The newly elected government in 1994 embarked on an electrification programme designed to provide electricity to households who had no access to electricity. However, the increase in electricity generation from this programme was driven by non-renewable energy sources such as coal (Department of Minerals and Energy, 1998). The period from the late 1990s to the early 2000s saw an increase in renewable energy consumption which peaked at just over 19% of total energy consumption in 2001. This could have been a of the introduction of the White paper on energy policy which was a formal support of the development of renewable energy resources by the government. However, between the period 2002 and 2009 renewable energy consumption declined sharply. In 2008 there was an energy crisis which resulted in load shedding as the demand for electricity outweighed supply. As such the period from 2009 to 2011 saw a slight increase in renewable energy consumption as alternative energy sources were explored. Renewable energy consumption, however, is still at very low levels.

**Figure 2: Trends in renewable energy consumption from 1990-2014**



**Source: World Bank (2017)**

### 3 Literature review

This section provides an empirical literature which consists of several studies that have examined the role of renewable energy consumption on an economy. The first part of the analysis surveys studies that have observed the impact of renewable energy consumption on economic growth while the second part looks at studies that have examined the role of renewable energy consumption in alleviating unemployment levels.

Amri (2017) concluded that there is a positive relationship between renewable energy consumption and economic growth in 72 developing and developed countries. Furthermore, there is a feedback relationship between the variables. Khobai and Le Roux (2017) examined the relationship between renewable energy consumption and growth in South Africa for the period 1990 to 2014. The authors reported that there is a long-run relationship between the variables. Furthermore, unidirectional causality from renewable energy to economic growth in the long-run and unidirectional causality from economic growth to energy consumption in the short-run.

Kahia et al. (2016) found that there is a long-run relationship between economic growth and renewable energy consumption for Net Oil Exporting countries during the period 1980-2012 using panel cointegration approach. Ibrahiem (2015) found that renewable electricity consumption and foreign direct investment have a long-run positive effect on economic growth in Egypt using the ARDL bound testing approach from the period 1980 to 2011. Omi, Mabrouk and Sassi-Tmar (2015) found that there is bidirectional causality between renewable energy consumption and economic growth in Belgium, Bulgaria, Canada, France, Pakistan and USA when examining the link between energy consumption and growth in 17 developed and developing countries.

Sebri and Ben-Salha (2014) concluded that there is a long-run relationship between renewable energy consumption, economic growth, carbon emissions and trade openness for BRICS countries. Furthermore, there is bidirectional causality between economic growth and renewable energy consumption. Apergis and Payne (2014) found that there is positive long-run relationship between renewable energy consumption, output, carbon emissions, coal prices and oil prices in seven Central American countries. Salim et al (2014) argue that there is a long-term equilibrium relationship on renewable energy and economic growth in OECD countries. Results indicate that in the short run there is a unidirectional causality between GDP growth



and renewable energy consumption over the period of 1980 to 2011 using the panel cointegration technique.

The relationship between renewable energy and unemployment has caused a lot of on-going debate around the globe and South Africa is not of exception. This study aims to provide empirical evidence on the impact of renewable energy on unemployment.

Bulavskaya and Reynès (2017) examined the impact of renewable energy on job creation in Netherlands using a neo-Keynesian CGEM ThreeME model. The authors concluded that the transition to renewable energy may create close to 50000 jobs by 2030 thus contributing 1% to GDP. Khodeir (2016) established an inverse correlation between renewable electricity generation and unemployment rate in Egypt over the period 1989 and 2013 using the ARDL approach. The study aimed to detect the effects in the short and long run during the study period, however, it has been found that the hypothesis was achieved in the long run only.

Bekmez and Ağpak (2016) investigated the relationship between non-hydro renewable energy and employment for a panel of 80 countries and concluded that there is unidirectional causality from employment to non-hydro renewable energy consumption for low to middle income countries and no causality for high income countries. The results therefore provide no support for the notion that renewable energy has a positive impact on unemployment.

Apergis and Salim (2015) investigated 80 countries from the period 1990-2013 using the advanced generation of unit root, cointegration and nonlinear Granger causality methodological approach in panel data. They obtained mixed results regarding the impact of renewable energy consumption on unemployment. However, total findings found that renewable energy consumption has a positive impact on unemployment, disaggregated data across specific regions, such as Asia and Latin America.

Rivers (2013) examined the impact of renewable electricity support policies on the rate of equilibrium unemployment utilizing a three-sector general equilibrium model. The study found that renewable electricity support policies lead to an increase in the rate of unemployment. Nevertheless, the study identifies conditions in which renewable energy support policies can reduce the rate of unemployment equilibrium. It is recorded that when the elasticity of substitution between capital and labour is low, capital internationally immobile, the labour intensity of renewable generation is high in relation to conventional generation, renewable electricity support policies may reduce the rate of unemployment.

Ragwitz et al. (2009) found that EU-wide renewable energy policies have generated a net positive impact on employment using an input-output framework and a macromodel. Lehr et al. (2008) investigated the relationship between renewable energy and unemployment in Germany and reported that the net effects of renewable energy on unemployment are positive.

#### 4 Data, methodology and empirical results

Data description, methodology and the empirical results are presented in this section. The data was sourced from the World Bank and covers the period from 1990 to 2014. Table 1 shows definitions of the variables used in the study.

**Table 1: Description of the variables**

Variable	Description
UR	Unemployment as a percentage of the labour force
INV	Gross fixed capital formation as a percentage of GDP
GOV	Government expenditure as a percentage of GDP
CRED	Credit to the private sector as a percentage of GDP
RE	Renewable energy consumption as percentage of total final energy consumption

**Source: World Bank (2017)**

##### 4.1 Descriptive statistics

Descriptive statistics are presented on table 2. Unemployment rate averaged close to 24% during the period of the study. The mean for Investments as a percentage of GDP is 18.02% which is lower than the level required. Renewable energy as a percentage of total energy consumption averages 17.28%. Government expenditure averages 19.22%. Credit to the private sector which is a proxy for financial development averages close to 131% which indicates that the South African financial sector is developed. Standard deviations of the variables indicate low levels of volatility apart from credit to the private. According to the Jarque-Bera statistic, apart from unemployment, all the variables are normally distributed.

##### 4.2 Correlation analysis

Table 3 shows the correlation between the variables in the study which can be used as a test for the presence of multicollinearity. Renewable energy is negatively correlated with credit to the private sector as well as investments which confirms a priori expectations. The correlations are

significant at the 1% level. Government expenditure is negatively correlated with unemployment but not significantly. According to table 3, correlations between the independent variables are below 0.8 which suggests that multicollinearity is not a problem in the study (Gujarati & Porter, 2009).

**Table 2: Descriptive statistics**

Variable	Mean	Standard deviation	Jarque-Bera statistic
UR	23.92	2.35	8.47**
INV	18.02	2.22	2.05
RE	17.28	1.03	1.43
GOV	19.22	0.80	0.83
CRED	130.75	17.89	1.53

Source: Researchers' own computations, Note: (\*\*) indicates significance at the 5% level.

**Table 3: Correlation analysis**

Variable	CRED	GOV	INV	RE	UR
CRED	1				
GOV	0.13	1			
INV	0.68****	0.34	1		
RE	-0.73****	-0.25	-0.86****	1	
UR	-0.14	0.06	-0.47**	0.39*	1

Source: Researchers' own computations, Note: (\*\*\*\*), (\*\*) and (\*) indicate significance at 1%, 5% and 10% levels respectively.

#### 4.3 Unit root tests

The unit root tests used in this study are the Augmented Dickey-Fuller (ADF) (Dickey & Fuller, 1981), the Phillips and Perron, (1988) and the DF-GLS test proposed by Elliot, Rothenberg and Stock (1996). The ADF and the Phillips-Perron tests have been criticised for their low power when variables are stationary but with a root close to non-stationary boundary (Brooks, 2008). Elliot et al. (1996) argue that the DF-GLS test has more power in the presence of an unknown mean or trend compared to the ADF and the Phillips-Perron tests. The null of a unit root is

tested against the alternative of stationarity in all tests. The unit root tests are run with and without a trend term and the results are presented on tables 4 and 5.

**Table 4: Unit root tests: With intercept only**

Variable	Levels			First difference		
	ADF	PP	DF-GLS	ADF	PP	DF-GLS
<b>CRED</b>	-1.79	-1.76	-0.65	-4.76***	-5.38***	-4.85***
<b>GOV</b>	-1.70	-1.71	-1.74*	-4.74***	-5.41***	-4.85***
<b>INV</b>	-2.04	-1.90	-1.98**	-3.27**	-3.18**	-2.95***
<b>RE</b>	-1.54	-1.86	-1.53	-3.92***	-3.81***	-3.41***
<b>UR</b>	-2.16	-2.14	-2.20**	-3.82***	-4.21***	-3.93***

Source: Researchers' own computations, Note: (\*\*\*), (\*\*) and (\*) indicate significance at 1%, 5% and 10% levels respectively.

**Table 5: Unit root tests: With intercept and trend**

Variable	Levels			First difference		
	ADF	PP	DF-GLS	ADF	PP	DF-GLS
<b>CRED</b>	-2.93	-3.01	-2.57	-4.65***	-5.27***	-4.90***
<b>GOV</b>	-2.17	-2.20	-2.35	-4.65***	-7.49***	-4.86***
<b>INV</b>	-2.93	-2.70	-2.59	-3.22*	-3.11	-3.30**
<b>RE</b>	-3.27*	-2.90	-2.42	-3.75**	-3.63**	-3.80***
<b>UR</b>	-2.53	-2.37	-2.54	-3.77**	-4.07**	-3.98***

Source: Researchers' own computations, Note: (\*\*\*), (\*\*) and (\*) indicate significance at 1%, 5% and 10% levels respectively.

The unit root tests presented on tables 3 and 4 indicate mixed results. According to the ADF and PP tests all the variables are integrated of order one regardless of whether a trend is present or not. The DF-GLS test suggests that investments and unemployment are I(0) in the absence of the trend term. However, with the trend term all the variables are I(1). Due to the mixed unit root results, the ARDL cointegration test is employed which allows variables to be integrated of different orders.

#### 4.4 ARDL bounds testing

This study considers the impact of renewable and non-renewable energy consumption on unemployment in South Africa within an autoregressive distributable lag (ARDL) bounds framework proposed by Pesaran et al (2001). The ARDL approach has a number of advantages over the other cointegration tests. Firstly, the test can be conducted with variables of varying orders of integration unlike tests such as the Johansen cointegration test which requires all variables to be integrated of order one. Secondly, the ARDL approach is robust in case of small sample sizes. Lastly, the technique utilised a reduced form equation compared to the system approach adopted by other techniques such as the Johansen test. Prior to the ARDL estimation, unit root tests are conducted to determine the order of integration of the variables and to confirm that there are no variables integrated of order two. Such variables will result in a crash of the ARDL approach.

The ARDL-bounds testing procedure is based on the ordinary least square estimation of a conditional unrestricted error correction model (UECM). One particularly attractive feature of this model is that it is applicable irrespective of whether the variables in the system are stationary in level (I(0)) or first differenced stationary (I(1)) or combination of both. However, the test cannot be employed with variables that are integrated of order two (I(2)). Pre-testing for order of integration that is associated with the conventional methods is only required to ensure that there are no I(2) variables.

The error correction version of the ARDL model specification for this study is given by:

$$\begin{aligned}
 \Delta UR_t = & \alpha_0 + \sum_{i=1}^p \alpha_{1i} \Delta UR_{t-1} + \sum_{i=0}^p \alpha_{2i} \Delta RE_{t-1} + \sum_{i=0}^p \alpha_{3i} \Delta NRE_{t-1} \\
 & + \sum_{i=0}^p \alpha_{4i} \Delta CRED_{t-1} + \sum_{i=0}^p \alpha_{5i} \Delta INV_{t-1} + \sum_{i=0}^p \alpha_{6i} \Delta GOV_{t-1} + \phi_{1i} UR_{t-1} \\
 & + \phi_{2i} RE_{t-1} + \phi_{3i} NRE_{t-1} + \phi_{4i} CRED_{t-1} + \phi_{5i} INV_{t-1} + \phi_{6i} GOV_{t-1} \\
 & + \varepsilon_t
 \end{aligned} \tag{1}$$

Where, UR is the unemployment rate, RE is the renewable energy consumption, CRED is the domestic credit to private sector. INV is the investment and GOV is the government expenditure. The first difference operator is denoted by  $\Delta$ , the drift component is given by  $\alpha_0$  and  $\varepsilon_t$  is the usual white noise residual.

Credit to the private sector as a proxy for financial development is expected to have a negative impact on unemployment. A more developed financial sector reduces the cost of capital which in turn promotes entrepreneurship, economic growth and employment levels (Caporale et al. 2015, Cojocaru et al. 2016). Investments is expected to be negatively signed as investments in production infrastructure increases employment levels directly in the fields in which the investments are made and indirectly through other related fields (Iacovoiu, 2012). Furthermore, investments may reduce unemployment by boosting economic growth. Government expenditure is goods and services boosts aggregate demand which in turn leads to an increase in demand for labour (Snowdon & Vane, 2005).

The implementation of the ARDL-bounds test approach involves two steps. In the first step, equation (1) is estimated using the OLS in order to determine the existence of long-run relationship between unemployment rate and relevant energy variables as well as the control variables. The long-run relationship is determined using the Wald-coefficient test or F-test for joint significance of the lagged level of the variables. In the present study, the null hypothesis of no co-integration is performed by setting  $\phi_1 = \phi_2 = \phi_3 = \phi_4 = \phi_5 = \phi_6 = 0$  against the alternative that  $\phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq \phi_5 \neq \phi_6 \neq 0$ . Similar restriction is imposed when other variables in equation (1) are used as dependent variables (Pesaran et al. 2001).

Pesaran et al. (2001) provide two sets of asymptotic critical value for the F-test. One set assumes that all the variables are I(0) and another assumes the variable are all I(1). The null hypothesis is rejected if the computed F-statistic is shown to be higher than the upper bound of the critical values. Conversely, if the computed F-statistic falls below the lower bound of the critical values, then the null hypothesis cannot be rejected. However, if the computed F-statistic falls within the band, then the result is inconclusive and prior information about the order of integration of the variable is necessary to make a decision on long-run relationships.

Once the long-run relationship is identified, the second step involves the estimation the long-run coefficients using the optimal number of lags. In the present study, the optimal number of lags is selected using the information criteria namely AIC and SBC.

The ARDL bounds testing results are illustrated in Table 6. The results affirm that there is existence of a long run relationship between unemployment, renewable energy consumption, investment, government expenditure and financial development. This is because the F-statistics of unemployment (4.51) is greater than the upper critical bound value of 4.37 at 1% level of significance. The null hypothesis of no cointegration is rejected at 1% level of significance.

**Table 6 Bound test results**

F-statistic	Critical values					
	1%		5%		10%	
<b>4.51***</b>	I(0)	I(1)	I(0)	I(1)	I(0)	I(0)
	3.29	4.37	2.56	3.49	2.2	3.09

**Source: Researchers' own computations, Note: (\*\*\*) indicates significance at the 1% level.**

The estimated coefficients of the long run relationship are illustrated in Table 7. Based on the findings in Table 7, the long run economic growth model can be moulded as follows:

$$UN = 109.81 - 3.72RE - 2.35INV + 0.28GOV + 0.12CRED$$

The estimated coefficients show that renewable energy consumption has a statistically significant negative impact on unemployment, which is line with economic theory that renewable energy decreases unemployment. More specifically, the long run elasticity of renewable energy consumption which is 3.72, implies that a percentage point increase in renewable energy consumption leads to a fall in unemployment by 3.72 percent points, all else held constant. The result confirms the findings of Khodeir (2016) who found that renewable energy consumption is negatively related to unemployment in Egypt.

Furthermore, it was established that investment has a negative and a significant effect on unemployment. All else the same, a percentage point increase in investment leads to a fall in unemployment by 2.35 percentage points. Government expenditure has a positive but insignificant impact on unemployment which is against *a priori* expectations as government expenditure is expected to enhance the demand for goods and services which in turn increases the demand for labour. However, government expenditures in wasteful activities might harm the economy and hinder the growth in employment levels. Lastly, the results suggest that financial development has a positive and a significant effect on unemployment. *Ceteris paribus*, a percentage point increase in financial development increases unemployment by 0.12 percentage points. The result is against *a priori* expectations as financial development is expected to boost the demand for goods and services, which in turn increases economic growth and employment levels.

**Table 7: Long-run coefficients ARDL(2,1,0,2,2)**

Variable	Coefficient	T-statistic
RE	-3.72	-2.15*
INV	-2.35	-3.51***
GOV	0.28	0.38
CRED	0.12	2.60**
C	109.81	2.51**

Source: Researchers' own computations, Note: (\*\*\*), (\*\*) and (\*) indicate significance at 1%, 5% and 10% levels respectively.

The short run results are presented in Table 8. These show that renewable energy consumption has a negative but insignificant effect on unemployment in the short run in line with the findings of Khodeir (2016) who concluded that the effect of renewable energy consumption on unemployment is only a long-run phenomenon. The results further reveal that government expenditure has a positive but insignificant effect on unemployment. Finally, financial development has a negative and significant impact on unemployment. More specifically, a percentage point increase in financial development leads to 0.08% decrease in unemployment, ceteris paribus. Financial development reduces unemployment in the short-run but increases unemployment in the long-run. A possible explanation for positive coefficient in the long-run is the rise in bad debts due to excessive credit which negatively impact on growth and unemployment levels. As shown above, credit to GDP ratio averages about 131% over the period 1990 and 2014.

**Table 8: ECM form**

Variable	Coefficient	T-statistic
$\Delta(\text{RE})$	-0.42	-0.96
$\Delta(\text{GOV})$	0.05	0.12
$\Delta(\text{CRED})$	-0.08***	-3.39
ECM(-1)	-0.69***	-6.49
R-Squared	0.83	
DW Statistic	1.78	

Source: Researchers' own computations, Note: (\*\*\*) indicates significance at the 1% level.



Based on the results illustrated in Table 8, the estimated coefficient of the  $ECM_{t-1}$  is -0.69. Since the error correction term is negative and significant, this implies that the results support the existence of a long run between the variables. The results indicate that departure from long-term growth path due to a certain shock is adjusted by 69% each year

**Table 9: Diagnostic tests**

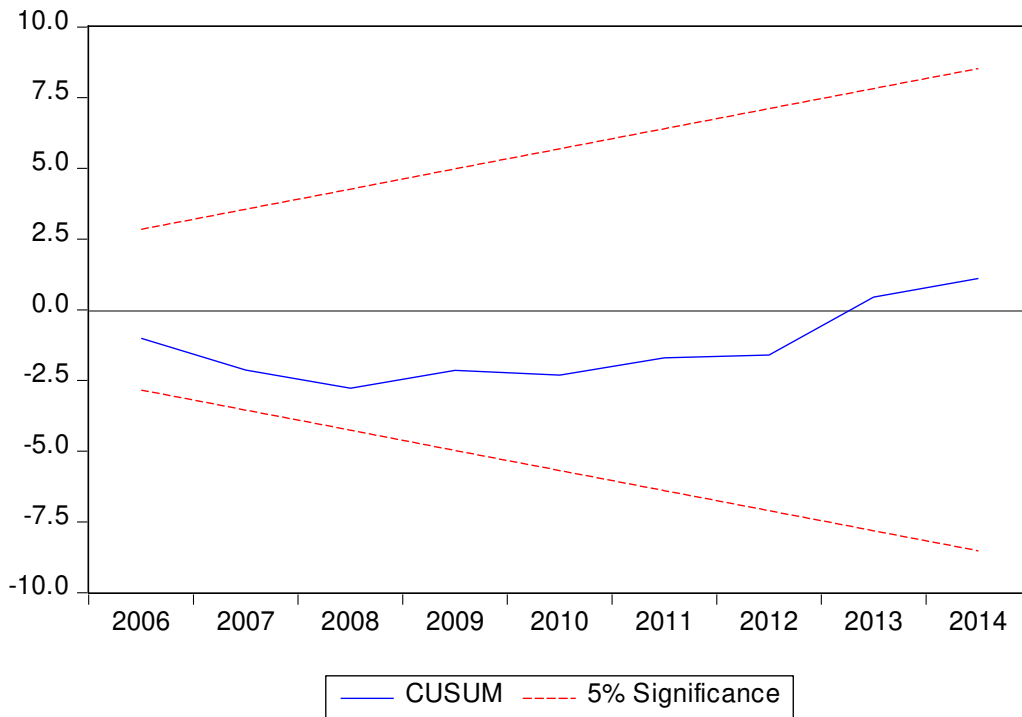
Test	Statistic	Probability
Normality	1.46	0.48
Heteroscedasticity	0.61	0.78
Serial correlation	0.05	0.95
RESET test	1.59	0.27

**Source: Researchers' own computations**

Diagnostic tests are performed to determine the adequacy of the model. The tests include the Breusch-Godfrey (1978) LM test for autocorrelation, the Breusch and Pagan (1979) test of heteroscedasticity, the Ramsey (1969) RESET test for model stability and the residual normality test. Table 9 shows the diagnostic test results. It was validated that the error terms of the short run models are free of heteroscedasticity, have no serial correlation and are normally distributed. It was also discovered that the Durbin Watson statistics is greater than the  $R^2$ , which implies that the short run models are not spurious.

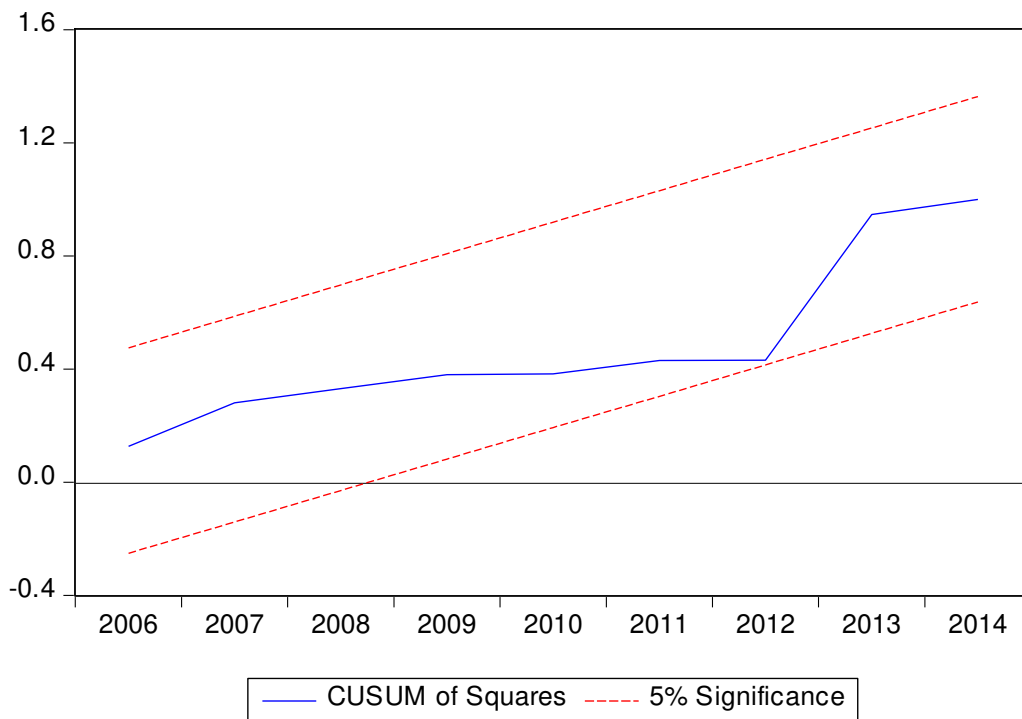
The stability of the long run parameters was tested using the cumulative sum of recursive residuals (CUSUM) and CUSUM of recursive squares (CUSUMSQ). The results are presented in Figures 3 and 4. The results fail to reject the null hypothesis at 5 percent level of significance because the plot of the tests fall within the critical limits. Therefore, it can be realised that our selected ARDL model is stable.

**Figure 3: CUSUM test**



**Source: Researchers' own computations**

**Figure 3: CUSUM of Squares test**



**Source: Researchers' own computations**

## 5 Conclusion

The study investigated the long-term and short-term impact of renewable energy consumption on unemployment in South Africa for the period of 1990 to 2014 using the ARDL model. Higher levels of renewable energy consumption may boost employment levels as renewable energy technologies are more labour intensive compared to non-renewable energy ones. South African is rich on renewable energy sources such as solar, wind and biofuels which could aid in alleviating the high unemployment rate which currently stands at over 25%.

The results suggest that renewable energy consumption and unemployment are negatively related in the long-run which implies that higher levels of renewable energy consumption enhance employment levels. However, the short-run results show that there is an insignificant relationship between the variables.

The study therefore advocates for an increase in the production and consumption of renewable energy in South Africa as this will reduce the high unemployment rate over the long-term. Higher employment levels will in turn to boost economic growth and improve standards of living. Barriers to the growth of renewable energy production and consumption such as high initial costs and high taxation should be eliminated in order to encourage investments in renewable energy technologies. Furthermore, the study recommends that government expenditure should be increased in labour intensive sectors in the economy which would boost employment levels. Investment levels in infrastructure should be increased in the economy as this will increase employment levels directly as well as indirectly through an increase in future economic growth. A regulatory framework should be strengthened to improve the screening of borrowers in order to reduce bad debts which hinder unemployment and economic growth.

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