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THE SUSTAINABILITY OF RENEWABLE ENERGY CONSUMPTION IN SOUTH AFRICA

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Abstract

Renewable energy sources are essential in reducing carbon emission levels and promoting a global green economy. The aim of this study is to examine the sustainability of renewable energy consumption per capita in South Africa by using the annual data for the period 1965-2018. For this purpose, in addition to traditional unit root tests, various unit root tests considering different structural changes are utilized in the study. According to the obtained results, the renewable energy consumption series in South Africa is found to be stable. Thus, it is concluded that sustainability is valid because the effects of one-unit shocks in energy use are not permanent.

Key words: Energy consumption, Sustainability, Time Series Analysis, Renewable Energy

JEL Code: Q2, Q43, Q48, Q56

1. Introduction

Energy has become an indispensable consumption item not only for industrialization but also for economic and social life. Energy consumption has gained importance in recent years. The total amount of energy consumed on earth increases depending on the level of development; thus, energy sources are needed for the existence and continuation of life. The demand for energy increases day by day. However, as the demanded energy is highly non-renewable energy and reserves decrease daily, the damages to our nature and human health emerge globally. Therefore, this situation is seen as a problem that needs to be solved urgently in the international arena and leads countries to review their energy policies and use their energy sources effectively.

Fossil fuels have been widely used in the last two centuries due to the cheap and advanced production technologies. However, with the 1973 Oil Crisis, there was an atmosphere of insecurity about energy resources. This environment of

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insecurity has caused oil-based energy consumption to be considered risky. Thus, interest in renewable energy has increased all over the world. Another development that has increased the interest in renewable energy is the increasing environmental awareness for the last thirty years. In recent years, the importance of renewable energy has increased due to factors such as the emergence of environmental problems with the increase of greenhouse gas emissions and geopolitical climate change due to fossil fuel production. Many countries around the world are organized to promote renewable energy while developing their energy policies.

Renewable energy consumption becomes an essential indicator since it is a natural and self-renewable energy source. Renewable energy, as energy from domestic production, also plays a leading role in reducing foreign dependency. For this purpose, in the study, it is suggested that South Africa should turn to renewable energy sources to decrease its dependency on foreign energy and to realize its social and economic development.

The sustainability of a variable depends on the permanence of the shocks applied to the variable. Therefore, researchers and policymakers discuss the static properties of energy consumption to distinguish the temporary and permanent characteristics of shocks. In the literature, temporary or permanent shocks are vital for the impact of policy outcomes with different perspectives. Recently, researchers have focused on evaluating the stagnation of energy consumption per capita using different unit root tests. Considering the close link between the energy and real economy, investigation of the time series properties of energy series is crucial for both researchers and policymakers. Therefore, testing the stagnation of renewable energy consumption increases the significance of policies to be carried out on energy and economy (Magazzino, 2016). Energy consumption has been gaining importance in recent years. Among the most critical reasons for this situation is the effect of energy on the productivity of capital and labor. In other words, energy consumption has always harmonized relations with an economic system and is vitally related to the economic system. Therefore, examining the sustainability of energy consumption is the focus of research studies.

When renewable energy consumption is stationary and does not contain unit roots, any shock in renewable energy consumption will have a temporary effect. Renewable energy consumption will return to the time trend, and such shocks will not harm macroeconomic policies. As a result, the stable process of the energy process shows that energy consumption in the past can be used to predict energy consumption and energy demand. On the other hand, if the renewable energy consumption process is not stationary (i.e., contains unit root), any shock in energy consumption will have a lasting effect. These shocks have a serious effect on energy consumption, and per capita renewable energy consumption cannot return to the balance level. Shocks in renewable energy consumption, also known as permanent effects, can be transferred to other sectors of the economy, including macroeconomic variables such as gross domestic product, growth rate of manufacturing sector, and capacity utilization rate (Bolat et al., 2013).

Thirty-five percent of African countries have energy problems. African countries being highly dependent on foreign energy have been looking for solutions with underground resources. African countries need to invest in renewable energy sources and use this potential in order to increase energy diversity and energy efficiency for improving the economy and quality of life of people. At this point, the basis of this research study is to examine the sustainability of renewable energy consumption in South Africa. This study aims to examine the sustainability of renewable energy consumption per capita in South Africa with various unit root tests. There are four sections in this paper. Following the introduction, in chapter 2, there is a literature review of the related literature on energy use. The data and research model utilized in this study is presented in Chapter 3, and findings are provided in Chapter 4. In the last section, the findings from the results of the analysis are discussed.

2. Literature Review

In the literature, there are many studies on stationarity and sustainability of energy consumption. However, research studies on renewable energy consumption are not frequently encountered; therefore, this study contributed to the literature. Narayan and Smyth (2007) initiated the discussion of unit root characteristics of energy consumption. Subsequently, researchers focused on studying the stability properties of energy consumption. Table 1 contains a summary of the research studies investigating the unit root test of energy consumption in the literature. While most studies showed unstable results in energy consumption, a limited number of studies in the related literature indicated stationary results in energy consumption. In Table 1 below, empirical studies examining whether energy consumption is stationary are given in detail.

Table 1. Studies Investigating Sustainability of Energy Consumption

Writers	Countries	Method	Period	Results
Masih and Masih (1996)	6 Countries (India, Pakistan, Indonesia, Malaysia, Singapore, Philippines	Dickey-Fuller (DF) Unit Root Test and Phillips-Perron (PP) Unit Root Test	1955-1990	Not stationary
Cheng and Lai (1997)	Taiwan	Phillips-Perron Testi	1955-1993	Not stationary
Glasure and Lee (1997)	South Korea and Singapore	ADF Unit Root Test	1961–1990	Not stationary
Yang (2000)	Taiwan	Phillips-Perron (PP) Unit Root Test	1954-1997	Not stationary
Soytaş and Sarı (2003)	10 Developing countries, G7 (excluding China)	Augmented Dickey-Fuller (ADF) Unit Root Test and Phillips-Perron (PP) Unit Root Test	1950-1994	Not stationary

Altınay and Karagöl (2004)	Turkey	Zivot-Andrews Unit Root Test	1950-2000	Stationary
Al- Iriani (2006)	Gulf Cooperation Council (GCC) Countries	ADF and IPS Unit Root Tests	1971–2002	Not stationary
Yoo (2006)	ASEAN Countries	Phillips-Perron (PP) Unit Root Test	1971–2002	Not stationary
Joyeux and Ripple (2007)	7 East Indian Ocean Countries	Levin, Lin, and Chu (2002) (LLC), Im, Pesaran and Shin (2003) (IPS) and Choi (2006) tests.	1971–2001	Not stationary
Zachariadis and Pashourtidou (2007)	Cyprus	Phillips-Perron (PP) Unit Root Test	1960–2004	Not stationary
Mishra et al. (2009)	13 Pacific Island Countries	Panel KPSS Test	1980-2005	5 countries are not stationary. It is stationary in 8 countries.
Alana et al. (2010)	America	ARMA	1973-2009	Not stationary
Apergis et al. (2010)	50 US States	Levin et al. (2002), Im et al. (2003), Maddala and Wu (1999), and Hadri (2000) panel unit root	1980-2007	Not stationary
Öztürk et al. (2010)	51 Countries	Im, Pesaran and Shin (IPS) Panel Unit Root Test	1971-2005	Not stationary
Agnolucci and Venn (2011)	Britain	Augmented Dickey-Fuller (ADF) Unit Root Test and Phillips-Perron (PP) Unit Root Test	1970-2004, 1978-2004	Not stationary
Hasanov and Telatar (2011)	178 Countries	ADF	1980-2006	It is stationary in 55 countries and not stationary in 123 countries.
Kula et al. (2012)	23 high-income OECD Countries	LM Unit Root Test	1960–2005	It is stationary in 21 countries and not stationary in 2 countries.
Kum (2012)	15 East Asia and Pacific Countries	Lee and Strazicich Unit Root Tests	1971-2007	Stationary
Bolat et al. (2013)	16 European Countries	KPSS Test	1960-2009	It is stationary in 15 countries outside of Luxembourg.
Shahbaz et al. (2015)	44 Countries	LM Unit Root Test	1965-2010	Not stationary in 57% of countries
Doğan (2016)	12 regions in Turkey (60 provinces)	Zivot-Andrews Unit Root Test	1995-2013	It is not stationary in 48 provinces,

				but stationary in 12 provinces.
Shahbaz et al. (2016)	103 Countries	Levin, Lin, and Chu (2002) (LLC), Im, Pesaran and Shin (2003) (IPS) and Choi (2006) tests	1971-2011	Not stationary
Khraief (2016)	Sub-Saharan African Countries	Lagrange Multiplier (LM) Panel Unit Root Test	1971-2013	11 of 17 countries are stationary.
Magazzino (2016)	19 European Union Countries	Im, Pesaran and Shin (IPS) Panel Unit Root Test	1960–2013	Stationary
Demir and Gozgor (2017)	54 Countries	Narayan-Popp Unit Root Test	1971-2016	Brazil, China, Colombia, India, Israel, Japan, the Netherlands, Spain, and Turkey are not sustainable.
Magazzino (2017)	19 European Union Countries	Zivot-Andrews Unit Root Test	1960–2013	Not stationary
Kızılkaya and Konat (2019)	Turkey	Fourier KPSS (FKPSS) Unit Root Test	1950-2017	Not stationary

Table 1 illustrates the research studies examining the sustainability of energy consumption in the world. In studies using different unit root tests, researchers concluded that energy consumption is not stationary, that is, unsustainable in all studies except in the studies by Altınay and Karagöl (2004), Kum (2012), and Magazzino (2016). The stationary feature of energy consumption shows that it is possible to predict future movements in energy consumption, based on temporary effects of any shock and past behavior of the series. Therefore, policymakers should be careful in looking at the characteristics of the energy consumption series.

3. Analysis

Research Question and Research Period

In this study, data on renewable energy consumption between 1965 and 2018 in South Africa were used in the analysis. The data set discussed in the study was obtained from United Nations Development Program (UNDP) and covers the period 1965-2017. Renewable energy consumption variable is composed of traditional biofuels, hydropower, solar, wind, and other renewables. The logarithm of the data was taken and included in the analysis. The data set considered is shown with the help of Graphic 1.

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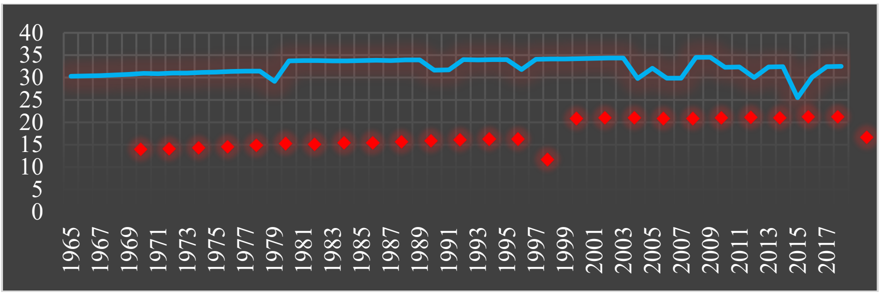
Graphic 1. Renewable Energy Consumption



Source: UNDP

Graph 1 shows the course of renewable energy consumption in South Africa between 1965 and 2017. As seen in the graph, renewable energy consumption has increased continuously from 1965 to 1979 followed by a decrease in consumption in 1979. The next serious decline took place in 2015. The African sustainable energy institute 2015 Energy Report mentions the warning that South Africa is experiencing an energy crisis and that it will deepen in 2020.

Descriptive statistics of the variable used in the analysis are provided in Table 2.

Table 2. Descriptive Statistic

Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jargue Bera
32.2601	32.367	34.536	25.513	1.868	-0.8879	4.164	10.148

Diagnostic statistics for renewable energy consumption are presented in Table 2. According to the results in Table 2, it was found that the mean and median values were close, and the skewness and kurtosis values were within the expected range.

Methodology

In addition to the traditional unit root tests, unit root tests with single and two structural breaks were used. In the literature, Zivot and Andrews (1992) introduced Zivot and Andrews (ZA) unit root test addressing a single structural break, and Lee and Strazicich (2013) defined Lagrange Multiplier (LM) unit root test. The unit root tests that allow two structural breaks, Narayan and Popp (2010) unit root test and LM unit root test (Lee and Strazicich, 2003), were utilized. Zivot and Adrews (1992) criticized the study of Perron (1989), who suggested that the break date was determined as preliminary; found the unit root test in which the break was determined internally (Zivot and Andrews, 1992).

ZA test statistics are shown as follows:

Model A $Y_i = \mu + \beta_t + \upsilon Y_{t-1} + \theta_1 DU(\alpha) + \sum_{i=1}^{k} \upsilon_i \, \Delta Y_{t-i} + \varepsilon_t$ (1)

Model B $Y_t = \mu + \beta_t + \upsilon Y_{t-1} + \theta_2 DT(\alpha) + \sum_{i=1}^{k} \upsilon_i \, \Delta Y_{t-i} + \varepsilon_t$ (2)

Model C $Y_t = \mu + \beta_t + \upsilon Y_{t-1} + \theta_1 DU(\alpha) + \theta_2 DT(\alpha) + \sum_{i=1}^{k} \upsilon_i \, \Delta Y_{t-i}$ (3)

While DU in model A, model B, and model C refers to the level of breaks, DT refers to slope breaks. The t = 1, 2, …….T indicates time, T_B shows break date, and the break point is shown as $\lambda = T_B/T$. Equation1, equation 2, and equation 3 with break points are estimated using Least Squares (LS). The break date is chosen as the date with the smallest t statistics (Zivot and Andrews, 1992). If the calculated t statistic is absolutely smaller than the critical value of ZA, indicating the unit root's existence with structural breaks, the null hypothesis is accepted. $DU_t(\lambda)$ shows the structural change, and when $t > T_B$, it is equal to 1, otherwise it gets the value of zero. $DT_t(\lambda)$ indicates the structural change in the slope and gets the value of $t - T_B$ when $t > T_B$, otherwise it gets the value of zero. The structural variation of the series is determined for the break date ranging from $i = 2/T$ to $i = (T - 1)/T$ by estimating each model with the LS method. Among the predicted equations, the t statistic, where the coefficient a is the smallest, is selected and compared with Zivot and Andrews (1992) table critical values. If the t statistic is greater than the table critical value, the H_0 hypothesis that indicates the existence of the unit root is rejected (Zivot and Andrews, 1992).

One of the structural break unit root tests, LM unit root test with single and two structural breaks, helps avoid the problem of rejecting false regression caused by ADF type unit root tests (e.g., ZA and Perron tests). ZA and LP unit root tests assume that there is no structural break in the null hypothesis that indicates the existence of unit root, and they calculate critical values based on this assumption. Lee and Strazicich (2004, 2013) revealed that the alternative to the null hypothesis used in these tests should not be "stationary with structural break" because the alternative to the null hypothesis may be the existence of structural breaks, which indicates that the unit root with structural break may exist in the examined series. Taking into account the structural breaks, the LS unit root test is based on the LM method. The data creation process of the LS unit root test is illustrated in the following equations.

$$y_t = \delta Z_t + e_t \qquad (4)$$
$$e_t = \beta e_{t-1} + \varepsilon_t$$

In these equations, Z_t denotes the vector containing external variables, whereas ε_t refers to residues showing the $iidN(0, \sigma^2)$ property. For the unit root test that allows a single break, Model A showing the shadow variable that gets the value when $D_{t,}\, t \geq T_B + 1$ and 0 in other cases 0 is obtained by placing $[1, t, D_t, DT_t]$ in Z_t in model (4). For unit root testing that allows two structural breaks, Model A is obtained while the shadow variable gets 1 when $t \geq T_{Bj} + 1$ for

D_{jt}, $j = 1, 2$ and gets the value of 0 in other cases by writing $[1, t, D_t, DT_t]$ in Z_t. Model C, which allows a single break in both level and slope, is explained while the shadow variable gets $t - T_B$ when DT_t, $t \geq T_B + 1$ gets the value of 0 in other cases by adding $[1, t, D_t, DT_t]$ in Z_t. LM unit root test statistics are obtained from the following regression:

$$\Delta y_t = \delta' \Delta Z_t + \emptyset \tilde{S}_{t-1} + u_t \qquad (5)$$

In the equation, the value of $\tilde{S}_t = y_t - \tilde{\psi}_x - Z\tilde{\delta}$, $\tilde{\psi}_x = y_1 - Z_1\tilde{\delta}$

In the study, other structural break unit root tests, applied to reveal whether renewable energy consumption is sustainable, were the Becker, Enders, and Lee (2006) Fourier function stationary test developed by Becker, Enders, and Lee (2006), and a new Dickey-Fuller (DF) type unit root test with Fourier function proposed by Enders and Lee (2012). Becker et al. (2006) did stationarity testing using the Fourier function's selected frequency component to estimate the deterministic components of the model. The test is designed to make the best estimate in case the breaks are gradual. Trigonometric terms are used to identify unknown nonlinear states, and the KPSS type stationarity test is suggested by emphasizing that the power of the unit-rooted zero hypothesis is decreased in stationary series. Becker et al. (2006) defined the data generation process with equation 6.

$$Y_t = X_t{}'\beta + Z_t'\gamma + r_t + \varepsilon_t \qquad (6)$$

$$r_t = r_{t-1} + u_t$$

$$Z_t = [\sin\left(\frac{2\pi kt}{T}\right) + \hat{\delta}_2 \cos\left(\frac{2\pi kt}{T}\right) \qquad (7)$$

ε_t represents stationary error term, and u_t shows fixed variance (δ_u^2) and is independent having an identical distribution. X_t'=1 is used for the level stationary process of Y_t while X_t'= (1,t) is utilized for the trend-stationary process. T is the number of observations, and k indicates the frequency number. When $\alpha(t)$ is as a function of the unknown number and structure of structural changes, Fourier structure can be shown as follows:

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} b_k cos\left(\frac{2\pi kt}{T}\right) \qquad n < \frac{T}{2} \qquad (8)$$

In order to use the F test, the stationary null hypothesis must not be rejected. Suitable critical values for the F test and the stationary test is included in the study by Becker et al. (2006) as a table.

Enders and Lee (2012) proposed a new Dickey-Fuller (DF) type unit root test with the Fourier function in the deterministic term. It has been stated that the use of Fourier tests is essential since it can reduce the strength of the test in case of being linear. Fourier tests take into account the DF test, as shown in equation # 9, where the deterministic term is represented by a time-dependent function such as α (t):

$$y_t = \alpha(t) + \rho y_{t-1} + \gamma t + \varepsilon_t \tag{9}$$

$$\Delta y_t = \rho y_{t-1} + c_1 + c_2 t\ c_3 sin\left(\frac{2\pi kt}{T}\right) + c_4\ cos\left(\frac{2\pi kt}{T}\right) e_t \tag{10}$$

4. Results

In this study, the sustainability of renewable energy consumption in South Africa examined with various unit root tests. Firstly, ADF and PP unit root tests, which are among the traditional unit root tests, were used. Since the traditional unit root tests do not take into account structural breaks, they are generally criticized for their tendency to reject the null hypothesis. For this reason, ZA and LS unit root tests taking into account structural breaks were used to observe the changes in the results under structural breaks. At the same time, the results obtained in different structural changes were discussed by considering the Fourier structure unit roots.

Table 3. Traditional Unit Root Tests

Test	Constant
ADF	-4.318 (0.000***)
PP	-4.293 (0.001***)

Not: *** means statistical significance at the %1 level.

The results of traditional unit root tests are shown in Table 3. Values in parentheses indicate probability values showing that there was no unit root in the series, and the effect of a unit shock applied to renewable energy consumption was not permanent. In such a case, it was decided that renewable energy consumption was sustainable for South Africa.

Table 4. One Break Unit Root Test Results

Test	Model A		Model C	
	Test Statistics	Critical Values	Test Statistics	Critical Values
ZA	-6.246 (1978)	-5,34, -4.80, -4.58	-6.199 (1978)	-5.57, -5.08, -4.82
LM	-5.413 (2003)	-4.23, -3.56, -3.21	-6.172 (2002)	-5.15, -4.45, -4.18

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In the related literature, it is stated that in cases where structural breaks are not taken into consideration, the series tend to contain unit roots. For this reason, energy consumption was also investigated using unit root tests, which considered structural breaks. The results are illustrated in Table 4. Values in parentheses represent the break dates. According to the results obtained from ZA unit root test and LM unit root tests based on ADF method, the series was found to be stationary as in traditional unit root tests. Assuming that the test statistics calculated in the model were larger than the relevant critical values and the unit root existed, the H_0 hypothesis was rejected, and the alternative hypothesis H_1 hypothesis was accepted. Thus, it can be stated that the sustainability is valid because the effects of shocks were not permanent.

Table 5. Two Break Unit Root Test Results

Test	**Model A**		**Model C**	
	Test Statistics	Critical Values	Test Statistics	Critical Values
ZA	-6.796 (1978-2002)	-4.958, -4.316, -3.980	-6.789 (2002-2006)	-5,57, -4,93, -4.59
LM	-5.867 (2003-2008)	-4.545, -3.842, -3.504	-6.794 (2002-2008)	-5.15, -4.45, -4.18

Table 5 displays the results of the ZA and LM unit root tests allowing two structural breaks under both null and alternative hypotheses. The test statistics calculated in the model were greater than the relevant critical values. Therefore, it was necessary to accept the hypotheses of unit root tests with two structural breaks. Hence, it was decided that the series is stationary and renewable energy in South Africa is sustainable.

Table 6. Fourier Fracture Unit Root Test

Test	**Constant**		**Constant and Trend**	
	Test Statistics	Critical Values	Test Statistics	Critical Values
ADF	-4.661	-4.42, -3.81, -3.49	-4.646	-4.95, -4.35, -4.05
KPSS	0.039	0.131, 0.172, 0.269	0.029	0.047, 0.054, 0.071

In Table 6, when per capita renewable energy consumption series was examined under the fourier function, it was seen that the ADF test statistic was greater than the table critical value and the expression of "there is no unit root with H_0 hypothesis" was accepted. Since KPSS test statistics were smaller than critical values, the unit root with H_0 hypothesis was rejected, H_1 hypothesis was accepted, and the series was determined to be stationary.

4. Conclusion and Recommendations

The possibility of continuing the use of fossil resources in energy production is decreasing day by day. The damages of the use of fossil fuels cause to the environment and human health all over the world is expected to put a heavy burden on mankind in the future. In this case, the need for increasing the use of renewable energy sources, which are the natural products of our environment instead of these energy sources, is better understood with each passing day. It is possible to prevent the dependence on external sources in energy, to take measures against the emergence of disruptions such as exhaustion and cutting, by increasing the energy types. With the use of renewable energy sources, dependency on imported fuels will decrease, priority will be given to domestic resources, employment will increase as a result of domestic production, sustainable economic growth will occur and welfare and stability will increase in social economic life. At this point, this is the main reason why we put forward this study. South Africa is energy dependent. The biggest reason for this dependency is seen as the insufficient economic policies of the governments and the inability to benefit from renewable energy sources such as wind, water and sun. Therefore, it is essential for African countries to invest in renewable energy sources in order to increase energy diversity and energy efficiency, to use this potential, to increase the economy and quality of life of the living people. In this study, the sustainability of renewable energy consumption in South Africa was examined. Firstly, ADF and PP unit root tests, which are traditional unit root tests, were used. Fourier fracture unit root tests were also used. As a result of unit root tests in both cases, it has been decided that renewable energy consumption is stable for South Africa. The fact that energy consumption has a steady course will result in the ineffectiveness of long-term energy policies due to temporary shocks. The stationary feature of energy consumption shows that it is possible to predict future movements in energy consumption, based on temporary effects of any shock and past behavior of the series. Therefore, policymakers should be careful in looking at the characteristics of the energy consumption series. At this point, social support should be provided to expand the use of renewable energy sources. First of all, it is necessary to believe the benefits of knowing the properties of the energy produced from these sources and to create public awareness.

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