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Green Growth Policies and Sustainable Economic Growth in South Africa: An Autoregressive Distributed Lag and Toda-Yamamoto Approach

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ABSTRACT

This paper investigates the long-run or sustainability effect and the causal relationship between green energy consumption, gross capital formation, gross domestic product (GDP), energy import and fuel export for South Africa between 1984 and 2015. The study adopts the bound testing approach to cointegration to check the long-run relationship, and the Toda-Yamamoto approach to determine the direction of causality. Results, indicate a positive unidirectional relationship between changes in green growth policies and gross capital formation. This finding suggests that adopting green growth policies lead to increased investments. In contrast, green growth was found to have a negative effect on GDP and absence of causality. The findings indicate a boost in the balance of payment as evidenced by the positive long-run relationship between green growth policies and fuel exports. Therefore, the study suggests the adoption and continued implementation of green growth policies in developing countries such as South Africa.

Keywords: Green Growth, Sustainable Economic Growth, Energy Imports, Fuel Exports, South Africa
JEL Classifications: QO2

1. INTRODUCTION

The debate on the adoption of good energy policies towards achieving economic growth or sustainable economic growth has led to different research interests in the field of energy and economics. Several studies have investigated the relationship between economic growth and energy consumption over the past three decades (Kraft and Kraft, 1978; Dutt, 1984; Ramcharran, 1990; Asafu-Adjaye, 2000; Smulders and De Nooij, 2003; Zhang and Cheng, 2009; Shahbaz et al., 2011). Consequently, the outcomes of these investigations remain completely diverse with positive, negative and even neutral relationships between the variables (Chtioui, 2012; Nnaji and Nnaji, 2013; Narayan and Narayan, 2010).

Given the continued interest of policymakers in achieving economic growth and development, there remains a need for empirical investigations which not only examine the relationship between energy consumption on economic growth, but also establish the direction of causality (Smulders and De Nooij, 2003; Odhiambo, 2009). Such investigations offer useful insights for policymakers and academics alike. Despite the myriads of empirical investigation on the relationship and direction of causality between energy consumption and economic growth in African countries, the non-inclusiveness of growth remains a major part of the energy policy debates. These debates are centred on both renewable and non-renewable sources of energy towards achieving sustainable growth or inclusive growths in different countries especially in Africa.

South Africa is faced with the dilemma of ensuring efficient energy production and distribution to ensure inclusive economic growth, this is despite the country's well-developed energy supply and production system. The main source of electricity in South Africa is coal, which accounts for 92% of the total electricity in the country, nuclear energy 7% while hydro and emergency gas turbines account for the remaining 1% (Eberhard, 2000).The policy makers and researchers must continue to divert attention towards a more efficient energy policies to achieve sustainable economic growth in South Africa. Although, very few empirical studies relating to green growth policy/green energy consumption have been carried out for only South Africa and panel investigations of countries including South Africa (Odhiambo, 2009; Odhiambo, 2010; Sebri and Ben-Salha, 2014; Bhattacharya et al., 2016; Khobai and Le Roux, 2017). The studies that included South Africa as one of the countries found positive and significant relationships between renewable energy and economic growth, but South Africa did not show significant or positive effects of renewable energy on economic growth (Bhattacharya et al., 2016; Sebri and Ben-Salha, 2014).

The outcome of the investigations on the relationship between green energy consumption and economic growth for South Africa showed unusual results compared to other countries investigated. Despite these findings, until date the role of renewable energy in promoting sustainable economic growth has not been fully researched empirically in the context of developing countries, including South Africa. In addition, based on the authors' knowledge, the empirical studies on the impact of renewable energy and gross domestic product (GDP) and other macroeconomic indicators did not consider its impact on energy imports and fuel exports (Odhiambo, 2009; Odhiambo, 2010; Menyah and Wolde-Rufael, 2010; Sebri and Ben-Salha, 2014; Bhattacharya et al., 2016; Khobai and Le Roux, 2017). This study aims to fill this gap by conducting an empirical investigation to check the sustainability effect of green energy consumption on economic growth and examine the impact on energy imports and fuel exports and gross capital formation in a multivariate framework. Therefore, the study has the purpose of finding out how the implementation of green growth policies in South Africa affects the GDP, fuel exports, energy imports and gross capital formation and consequently leading to sustainable economic growth.

The study utilised the autoregressive distributed lag (ARDL) bounding test developed by Pesaran et al. (2001) to determine the long-run relationship between green energy consumption and GDP, fuel exports, energy imports, and gross capital formation between 1984 and 2015. The establishment of a long-run relationship between the dependent variable (green energy consumption) and the explanatory variables will directly explain the sustainability effect of the green energy consumption/green growth policies on economic growth. The Toda-Yamamoto Granger causality approach will also be examined to determine the direction of causality between the variables. The Toda-Yamamoto approach is irrespective of whether the unit root test is integrated of order I (0), I (1) or even I (2), and can be cointegrated or not cointegrated of any arbitrary order. The direction of causality will be examined in this study to provide insights for policy implications in South Africa and other developing countries.

A notable reason for choosing South Africa as the laboratory in this study is the divergence from other countries in the results of the empirical investigations conducted on the impact of renewable energy on economic growth when selected in a panel study (Bhattacharya et al., 2016; Sebri and Ben-Salha, 2014). The economy of South Africa is also energy intensive with about 15% of the GDP being generated from the energy sector and mainly from coal (Department of Minerals and Energy, 2008).

Amongst other developing countries, another good reason for selecting South Africa as a laboratory for providing insight within an international context is because of the various energy programmes and policies adopted by South Africa to meet the demands from its highly energy intensive economy. This is despite the structural transformation of the energy policies and programmes concerning the transition from the apartheid to post-apartheid era. The journey toward South Africa's large-scale deployment of renewable energy technologies is a combination of government policy interventions and market forces between 2008 and 2012; the aim was to achieve a world-class programme. South Africa is richly endowed with coal, forming the largest part of its energy generation; South Africa is not only rich in green energy sources namely wind and sunshine. South Africa has one of the highest solar radiations in the world with more than 2500 h of sunshine yearly with an average radiation level of between 4.5 and 6.5kWh/m^2/day making it one of the top three countries in the world in this regard (Department of Energy [DoE], 2015). Therefore, the structural transformation of the energy sector as a result of the transition from the apartheid to the post-apartheid period and the endowment of the green energy sources (wind and solar) necessitates this study.

The remaining part of this study is arranged as follows: Section 2 analyses the theoretical and empirical literature review. Section 3 explains the estimation techniques and empirical analysis. Section 4, carries out the conclusion of the study and analyses the policy implication and recommendations.

2. LITERATURE REVIEW

A plethora of literature exists on the relationship and direction of causality between renewable energy and economic growth in different countries around the world. These empirical investigations either found a positive or negative relationship between renewable energy consumption on economic growth in a panel data investigations or individual countries. This positive or negative relationship can also be either significant or insignificant relationships between renewable energy consumption and economic growth. For example, an empirical investigation was conducted to determine the effects of renewable energy on macroeconomic efficiency of 45 OECD and non-OECD countries by Chien and Hu (2007). The study established that an increase in the consumption of renewable as a significant part of the total energy mix will have a positive impact on technical efficiency. Whereas, the increase in traditional energy (total energy supply-renewable energy) decreases technical efficiency.

A panel investigation of fifteen European countries where conducted by Okyay et al. (2014) to find the relationship between economic growth, renewable energy, and non-renewable energy within a multivariate framework. The authors found that an increase in renewable energy leads to a corresponding increase in real GDP. A multivariate framework of sixteen countries was also conducted by Apergis and Payne (2010) to investigate the relationship between nuclear energy consumption, economic growth, labour force, and real gross capital formation. The authors found a statistically significant and positive relationship between the variables. Bhattacharya et al. (2016) investigated the impact of renewable energy on economic growth of 38 top renewable energy consuming countries, including South Africa. The study established the presence of a long-run relationship between economic growth and traditional energy, heterogeneity, and cross-sectional dependence amongst the 38 countries; although about 57% of the countries showed a positive and significant impact of renewable energy on economic growth. However, the study also failed to establish a significant impact of renewable energy on economic growth in South Africa and ten other countries. This implies that, renewable energy was not established to be a driver or barrier to economic development in those eleven countries.

The impact of renewable energy consumption on economic growth were conducted for BRICS countries (Brazil, Russia, India, China, and South Africa) by Sebri and Ben-Salha (2014). The study found a long-run relationship among the variables (trade openness, economic growth, carbon dioxide emission and renewable energy. However, India and South Africa showed no significant or positive effect of renewable energy consumption on economic growth and vice versa.

Similarly, empirical investigations to reveal the relationship between renewable energy and economic growth for individual countries also established diverse results (positive and negative). In the case of the Indonesian economy, Arifin and Syahruddin (2011) established a positive relationship between renewable energy consumption and economic growth. In a production function framework in Brazil, Pao and Fu (2013) also found a positive and statistically significant relationship between renewable energy, capital, labour, and real output. Maji (2015) found a negative relationship between renewable energy and economic growth in Nigeria. Ibrahiem (2015) found a long-run relationship between renewable energy, economic growth and foreign direct investment in Egypt. However, the outcome of the study on the United States conducted by Ewing et al. (2007) showed the presence of slight divergence from other studies as it revealed a strong impact of non-renewable energy on output, while a little or considerable impact was shown by renewable energy.

The empirical investigations concerning the direction of causality also found either unidirectional, bidirectional or neutral causality. These empirical investigations started with the work of Kraft and Kraft (1978). The authors established a bidirectional causality between energy consumption and gross national product. In consistence with the foremost study on the direction of causality, Pao et al. (2014), Apergis and Payne (2011), Tugcu et al. (2012), Ibrahiem (2015) established a bidirectional causality between economic growth and renewable energy within developed and emerging economies. Whereas, Khobai and Le Roux (2017) found unidirectional causality running from renewable energy to economic growth in South Africa. Therefore, the outcome of the direction of causality shows high level of divergence on the investigations conducted in some countries and South Africa.

3. METHODOLOGY AND DATA

The analysis in this section is based on time-series data pertaining to the rate of renewable energy sources adopted in South Africa and relevant macroeconomic and institutional variables. The time-series econometrics is mainly concerned with the estimation and inferences on models whose specifications are usually derived from economic theory. This model specification involves a number of the explanatory variables or independent variables and addresses the issue of endogeneity. In a situation where time-series analysis is not intended for inference, then its objective will be to examine the direction of granger-causality between a set of time-series variables. Despite this fact, the focus of the test is to scrutinise the direction of causality; with the objective to do forecasting. This is not to undermine the main focus of the time-series analysis which is to examine the impact of a dependent variable on the explanatory variables and vice versa (Ashley, 2012).

This section of the study attempts to examine the relationship between green energy/green growth policies and some macroeconomic variables toward sustainable economic growth. The general form of the neoclassical model of production and growth function is followed in the approaches used by (Ogundipe and Akinyemi, 2014; Khobai and Le Roux, 2017; Nnaji and Nnaji, 2013; Akinwale et al., 2013; Akpan and Akpan, 2012).

$$Y=AK^{\alpha}L^{\beta} \tag{1}$$

The study examines the impact of green growth policies on some macroeconomic variables as stated below:

$$GRGt=F\ (GDP_t, GKF_t, EI_t, FE_t) \tag{2}$$

The dependent variable and the explanatory variables included in the model above coincides with that of Ackah and Kizys (2015), Lin and Moubarak (2014) and the analysis of Fay (2012). GRG_t is green energy policies at time t, represented by alternative and nuclear energy. It is supported by some national energy policies such as the national energy efficiency strategy, the White Paper for 2003, the cleaner fuel programme and the green growth path: Accord 4. GDP_t is the GDP growth rate at time t. The GDP growth rate represents the goal 8 of the SDGs (United Nations, 2016). GKF_t is the gross capital formation at time t, is energy import at time t and is the fuel export at time t. The expression in equation (2) can also be written in an explicit form as shown below:

$$GRG_t=\alpha_1+\delta_1 GDP_t+\lambda_1 GKF_t+\pi_1 EI_t+v_1 FE_t \tag{3}$$

The equation is continued by obtaining the stochastic form of equation (3). The stochastic form will assist to ensure an appropriate treatment of the time-series data.

$$GRG_t=\alpha_1+\delta_1 GDP_t+\lambda_1 GKF_t+\pi_1 EI_t+v_1 FE_t+\varepsilon \tag{4}$$

Equation (4) above is necessary for an adequate treatment of the time-series data. Although the time-series data is an important type of data, it poses some challenges to econometricians and practitioners. These challenges are: Firstly, the problem of stationarity. Secondly, autocorrelation also occurs as a result of stationarity. Thirdly, time-series often yields a high R^2, sometimes in excess of 0.9 (90%) relationship which does not necessarily imply that there is a meaningful relationship between the variables. This is a sign of spurious or nonsensical regression. Fourthly, time-series analysis may exhibit the random walk phenomenon. Fifthly, regression models incorporating time-series data are usually good for forecasting when the underlying time-series are not stationary. Lastly, the causality test is based on an assumption that the time-series analysis is stationary. Therefore, the test of stationarity will be done before the tests of causality (Gujarati, 2013).

3.1. Bounds Testing Approach to Cointegration

The Bounds testing approach to co-integration analysis has been adopted by different authors to determine the long-run relationship between energy consumption and GDP or carbon dioxide emission (Ozturk and Acaravci, 2010; Okyay et al., 2014; Akpan and Akpan, 2012). The ARDL bounds approach to co-integration requires the presence of I (0) or I (I) variable, that is being stationary at the level form or at first difference. Hence the need to determine the order of integration as the Bounds test will not hold in the presence of I (2) (Frimpong and Oteng-Abayie, 2006).

This approach is preferred in this study for some salient reasons compared to other co-integration techniques like Engle and Granger's causality technique, Johansen and Johansen and the 1 without necessarily considering the classification of variables into I (1) or I (0) and do not require unit root pre-testing. Secondly, while there is the need for large data samples in Johansen's co-integration for validity, the ARDL procedure is a more statistically significant approach to determining variables that have different optimal lags. This is not possible with conventional co-integration procedures. Lastly, the ARDL procedure employs a single reduced form equation instead of the conventional co-integration procedures to estimate the long-run relationship by adopting system equations (Ozturk and Acaravci, 2010). The equations below present this study's ARDL form.

$$\Delta GRG_t = \begin{aligned} &\alpha_1 + \sum_{i=1}^{p}\beta_1\Delta GRG_{t-1} + \sum_{i=0}^{p}\delta_1\Delta GDP_{t-1} + \sum_{i=0}^{p}\lambda_1\Delta GKF_{t-1} + \\ &\sum_{i=0}^{p}\pi_1\Delta EI_{t-1} + \sum_{i=0}^{p}v_1\Delta FE_{t-1} + \eta_{1Y}GRG_{t-1} + \eta_{2Y}GDP_{t-1} + \\ &\eta_{3Y}GKF_{t-1} + \eta_{4Y}FE_{t-1} + \eta_{5Y}EI_{t-1} + \varepsilon_t \end{aligned} \quad (5a)$$

$$\Delta GDP_t = \begin{aligned} &\alpha_2 + \sum_{i=0}^{p}\beta_2\Delta GRG_{t-1} + \sum_{i=1}^{p}\delta_2\ \Delta GDP_{t-1} + \\ &\sum_{i=0}^{p}\lambda_2\Delta GKF_{t-1} + \sum_{i=0}^{p}\pi_2\Delta EI_{t-1} + \sum_{i=0}^{p}v_2\Delta FE_{t-1} + \\ &\eta_{1N}GRG_{t-1} + \eta_{2N}GDP_{t-1} + \eta_{3N}GKF_{t-1} + \\ &\eta_{4N}EI_{t-1} + \eta_{5N}FE_{t-1} + \varepsilon_{2t} \end{aligned} \quad (5b)$$

$$\Delta GKF_t = \begin{aligned} &\alpha_3 + \sum_{i=0}^{p}\beta_2\Delta GRG_{t-1} + \sum_{i=1}^{p}\delta_3\Delta GDP_{t-1} + \\ &\sum_{i=0}^{p}\lambda_3\Delta GKF_{t-1} + \sum_{i=0}^{p}\pi_3\Delta EI_{t-1} + \sum_{i=0}^{p}v_3\Delta FE_{t-1} + \\ &\eta_{1R}GRG_{t-1} + \eta_{2R}GDP_{t-1} + \eta_{3R}GKF_{t-1} + \\ &\eta_{4R}EI_{t-1} + \eta_{5R}FE_{t-1} + \varepsilon_{2t} \end{aligned} \quad (5c)$$

$$\alpha\,\Delta EI_t = \begin{aligned} &\alpha_4 + \sum_{i=0}^{p}{}^{2}{}_{4}\Delta GRG_{t-1} + \sum_{i=0}^{p}\delta_4\Delta GDP_{t-1} + \sum_{i=0}^{p}\lambda_4\Delta GKF_{t-1} + \\ &\sum_{i=1}^{p}\pi_4\Delta EI_{t-1} + \sum_{i=0}^{p}v_4\Delta FE_{t-1} + \eta_{1C}GRG_{t-1} + \eta_{2C}GDP_{t-1} + \\ &\eta_{3C}GKF_{t-1} + \eta_{4C}FE_{t-1} + \eta_{5C}EI_{t-1} + \varepsilon_{4t} \end{aligned} \quad (5d)$$

$$\Delta FE_t = \begin{aligned} &\alpha_5 + \sum_{i=0}^{p}\beta_5\Delta GRG_{t-1} + \sum_{i=0}^{p}\delta_5\Delta GDP_{t-1} + \sum_{i=0}^{p}\lambda_5\Delta GKF_{t-1} + \\ &\sum_{i=0}^{p}\pi_5\Delta EI_{t-1} + \sum_{i=1}^{p}v_5\Delta FE_{t-1} + \eta_{1T}GRG_{t-1} + \eta_{2T}GDP_{t-1} + \\ &\eta_{3T}GKF_{t-1} + \eta_{4T}FE_{t-1} + \eta_{5T}EI_{t-1} + \varepsilon_{5t} \end{aligned} \quad (5e)$$

In the ARDL equations the Δ is the first difference operator of the models. The parameters β δ, λ, π and v in the ARDL model represents the dynamic coefficient in the short-run while the long-run multipliers are denoted by η_{1T}, η_{2T}, η_{3T}, η_{4T} and η_{5T} the number of lags denoted by p.

In the first ARDL regression model ΔGRG_t are the endogenous variables and other exogenous variables are macroeconomic variables. This study seeks to find the presence of co-integration, using the F-test to examine the lagged levels of the variables or the Wald test. The null hypothesis of no integration will be: H_0: $\eta_1 = \eta_2 = \eta_3 = \eta_4 = 0$ and the alternative hypothesis H_0: $\eta_1 \neq \eta_2 \neq \eta_3 \neq \eta_4 \neq 0$. In the ARDL approach, two sets of critical values are usually provided: The value which will be applicable when all the series are co-integrated by 1(0) and the other will stand for all the values that are co-integrated by I (1).

3.2. Granger Non-causality Test Approach

The causality test can be referred to as the ability of a variable to help predict and cause another variable. The VAR model captures the relationship between the variables, for example, GRG and GDPG. The approach captures how both variables affects each other with some distributive lags. In other words, the model shows how the GRG causes GDP and how GDP causes GRG. Hence, there is an existence of a bidirectional feedback between the variables which is usually captured by the VAR model irrespective of the independent relationship between the variables.Therefore, the feedback can be a directional, undirectional causality, neutral or independent effect among the variables. The Granger-causality technique is often used to determine the possibility of a variable assisting to predict another variable by adopting the F-test, e.g., adopting the F-test in this study to examine whether the

GDP provides a statistically significant outcome with GRG. If the outcome proves to be significant, the study can conclude that GDP Granger-causes GRG and vice versa. In other words, if the outcome of the study shows that it is insignificant, it means there is an absence of causality between the variables.

The causality test in this study adopts a modified Wald test (MWALD) proposed by Toda and Yamamoto (1995). The Toda-Yamamoto (TY) approach to causality avoids the problems identified with the traditional causality tests like the Granger-causality test stated above. The Toda-Yamamoto approach to causality is not associated with the need to determine stationarity or co-integration between series. Therefore, the Toda-Yamamoto approach is valid whether a series is I(0), I(1) or even I(2) and the series may not be co-integrated of any arbitrary order (Rambaldi and Doran, 1996; Menyah and Wolde-Rufael, 2010). However, the Toda-Yamamoto approach is better than the conventional Granger-causality approach as it is not affected by possible bias associated with unit root and co-integration tests. The TY is estimated based on augmented VAR modelling that employs a Wald test statistic that is asymptotically Chi-square distributed, notwithstanding the order of integration or co-integration of the variables. The TY approach estimates a standard vector auto-regressive order on the levels of the variables and not on their first difference. Therefore, the TY approach takes into consideration long-run information that is usually ignored by taking the first differencing of variables and pre-whitening (Kum et al., 2012; Menyah and Wolde-Rufael, 2010).

To be consistent with the studies of Menyah and Wolde-Rufael (2010), and Ocal and Aslan (2013), this study develops the model of the TY Granger non-causality test for VAR having 4 lags (k = 3 and d_{max} = 1). This research will estimate the next system equation as below:

$$\begin{Bmatrix} GRG_t \\ GDP_t \\ GKF_t \\ FE_t \\ EI_t \end{Bmatrix} = A_0 + A_1 \begin{Bmatrix} GRG_{t-1} \\ GDP_{t-1} \\ GKF_{t-1} \\ FE_{t-1} \\ EI_{t-1} \end{Bmatrix} + A_2 \begin{Bmatrix} GRG_{t-2} \\ GDP_{t-2} \\ GKF_{t-2} \\ FE_{t-2} \\ EI_{t-2} \end{Bmatrix} + A_3 \begin{Bmatrix} GRG_{t-3} \\ GDP_{t-3} \\ GKF_{t-3} \\ FE_{t-3} \\ EI_{t-3} \end{Bmatrix} + A_{\square} \begin{Bmatrix} GRG_{t-\square} \\ GDP_{t-\square} \\ GKF_{t-\square} \\ FE_{t-\square} \\ EI_{t-\square} \end{Bmatrix} + \begin{Bmatrix} \varepsilon \;\, GRG_t \\ \varepsilon \;\, GDP_t \\ \varepsilon \;\, GKF_t \\ \varepsilon \;\, FE_t \\ \varepsilon \;\, EI_t \end{Bmatrix} \quad (6)$$

Equation (6) above shows that A_1, A_2, A_3 and A_4 are 5 by 5 matrices and the coefficient of A_0 as the representative of the 5 by 1 identity matrix. The ε represents the disturbance term with zero mean and constant variance. The study will estimate the null hypothesis that green energy consumption (GRG_t) does not granger-cause economic growth (GDP_t). This will be achieved with the following hypothesis: $H_0 = a^1_{12} = a^2_{12} = a^3_{12} = 0$. However, a^1_{12}, a^2_{12}, and a^3_{12} represents the coefficient of the GDP variable in the first equation of the system presented in equation (6) above.

On the other hand, the study can also test the non-causality from (GDP_t) to (GRG_t) in the following hypothesis: $H_0 = a^1_{21} = a^2_{21} = a^3_{21} = 0$. Therefore, a^1_{12}, a^2_{12}, and a^3_{12} are the coefficients of the green growth (GRG_t) equation presented in equation (6) above. The test between green growth (GRG_t) and other explanatory variables, such as gross capital formation (GKFt), fuel export (FE_t) and energy import (EI_t) will be conducted.

The study further employed the Ramsey RESET test to verify the possibility of misspecification of data, the heteroscedasticity test to check the disturbances in the model, the Breusch-Godfrey test to check for the presence of serial correlations and the normality tests. The outcomes of these tests were suitable, as they showed a possibility of sustainability of the economy from an adequate implementation of green growth policies.

4. EMPIRICAL ANALYSIS

The high relevance of unit root to economics is due to the theoretical implication of models that requires the effective use of information that is available to them. Another notable reason is that the unit root tests can be adopted to estimate the non-stationarity and stationarity nature of most macroeconomic data. The unit root test is also very important in detecting if a trend is stochastic or deterministic by checking for the presence of a polynomial time trend (Philips and Perron, 1988). Diagnostic tests for the selected optimal lag is presented in Table 1.

This study adopts the Augmented Dickey Fuller (ADF) and the Philips Perron (PP) unit root tests. The result of the tests are presented in Tables 2-5 accordingly. The result of the two methods of unit root tests exhibits stationarity at both I(0) and I(1) but none of the variables were integrated at I(2) or more.

4.1. Cointegration Test

This section of the paper tests for co-integration between the variables to determine whether long-term relationships between the variables exist. The ARDL procedure was adopted in the research. The application of the ARDL approach was possible, since the series was integrated of both level or I(0) and first difference or I(1) based on the augmented Dickey-Fuller and Philips Perron unit root tests. In this study the test for co-integration between the green energy policies representative and the macroeconomic variables were conducted based on Pesaran et al. (2001).

The F-statistics is the ARDL test of statistics, the critical values for the lower bound I(0) and the upper bound I(1) was conducted according to Pesaran et al. (2001).

The results in Table 6 reveal the value of the F-statistic as 5.699967 at 4 degrees of freedom and the critical lower and upper bounds at

Table 1: Diagnostic tests for the selected optimal lag

Test statistics	LM version	F version
A: Model specification	CHSQ (22)=0.320760 (0.7514)	F (1.22)=0.102887 (0.7514)
B: Normality	CHSQ (7)=0.398574 (0.819315)	N/A
C: Heteroscedasticity	CHSQ (7)=1.815931 (0.9693	F (7.23)=0.204448 (0.9811)
D: Serial correlation	CHSQ (1)=0.578986 (0.4467)	F (1.22)=0.418714 (0.5243)

A: Ramsey's RESET techniques by adopting the sum of the squared of the fitted lines, B: Based on the Jarque-Bera (JB) test of skewness and kurtosis of residuals, C: Based on the Breusch-Pagan Godfrey of the observed R-squared, D: The application of the Breusch-Godfrey serial correlation LM test

Table 2: Stationarity test of variables in levels - ADF

Variables	No trend	Trend
GRG	−4.2972**	−4.1198**
GKF	3.27027**	−3.25454**
GDP	−3.55617***	−3.83261**
FE	−1.80978	−4.01911**
EI	−2.19665	−1.46074

The critical values are according to Elliot and Harackiewicz (1996) and **, ***denote 5% and 1% level of significance respectively. ADF: Augmented Dickey-Fuller

Table 3: Stationarity test of variables in levels - PP tests

Variable	No trend	Trend
GRG	−4.30438**	−4.12845**
GKF	−3.27027**	−3.25552
GDP	−3.63933**	3.76558**
FE	−1.80978	−3.88448**
EI	−1.43566	−2.22104

The critical values are according to Elliot and Harackiewicz (1996) and **, ***denote 5% and 1% level of significance respectively. PP: Philips Perron

Table 4: Stationarity test of variables in first difference - ADF

Variable	No trend	Trend
GRG	−7.91871***	−8.05264***
GKF	−5.55807***	−5.57231***
GDP	−2.39114**	−4.55375***
FE	−6.5547***	6.43675***
EI	−5.92021***	5.76909***

The critical values are according to Elliot and Harackiewicz (1996) and **, ***denote 5% and 1% level of significance respectively. ADF: Augmented Dickey-Fuller

5% of the Pesaran et al. (2001), is 2.86 and 4.01 for I(0) and I(1). The value of the F-statistic exceeds the upper bound at the 5% significant level, which is 5.699967. It can therefore be concluded that there is evidence of a long-run relationship between GRG (green growth) and the set of other independent or explanatory variables like gross capital formation (GKF), fuel export (FE), energy import (EI) and GDP.

The results in Table 7 are not far removed from the direction of relationship in the short-run, but all the variables employed are significant at the 10% level, GDP and energy import are significant at 5%. The long-run relationship reveals a positive insignificant relationship between green growth and the independent variables gross capital formation (GKF) with (0.202478), and fuel export (FE) with (0.110291) at 5% level of significance. Therefore, the study established that gross capital formation and fuel export have insignificant and positive relationships with the green growth variable at 5% level of significance. GDP and Energy import (EI) reveal an indirect and significant relationship of (−0.190650)

Table 5: Stationarity test of variables in first difference - PP tests

Variable	No trend	Trend
GRG	−8.05215***	−8.24327***
GKF	−7.38591***	−9.64272***
GDP	−13.8566**	−7.72626***
FE	−15.303***	−15.292***
EI	−5.91695***	−5.76704***

The critical values are according to Elliot and Harackiewicz (1996) and **, ***denote 5% and 1% level of significance respectively. PP: Philips Perron

Table 6: ARDL bounds F-test for cointegration

Test statistic k	Value	k
F-statistic	5.699967	4
Critical value bounds		
Significance	I0 bound	I1 bound
Critical values at 10%	2.45	3.5
Critical values at 5%	2.86	4.0
Critical values at 2.50%	3.25	4.4
Critical values at 1%		5.0

The F-statistics is the ARDL test of statistics, the critical values for the lower bound I (0) and the upper bound I (1) was conducted according to Pesaran et al. (2001). ARDL: Autoregressive distributed lag

and (−0.081602) respectively at the 5% level of significance with green energy. This implies that the green energy consumption variable has a significant and negative effect on GDP and energy import. The negative relationship between green growth and GDP was consistent with Ocal and Aslan's study (2013). Their study established a negative relationship between renewable energy consumption and economic growth. The study conducted for 38 countries on the adoption of renewable energy, including South Africa by Bhattacharya et al. (2016) established that renewable energy is not a significant driver of economic growth.

Having established the long-run stochastic trend or co-integration among the green energy policies variable and the explanatory variables which are GDP and Energy import (EI), Gross capital formation (GKF), and Fuel export (FE). Furthermore, the study evaluated the error correction model of the variables to evaluate both the short-run and long-run effect of the time-series data for each of the variables.

Therefore, the ECM summarised in Table 8 was employed to estimate the speed at which the green energy variable returns to equilibrium after a change in any of the explanatory variables. The results in Table 8 show the error correction mechanism. It is the dynamic adjustment to the disequilibrium in the short-run. The ECM coefficient is the most important value under consideration and the result shows that the ECM coefficient is well defined in

Table 7: Long-run coefficients, dependent variable GRG

Regressors	Coefficient	Standard error	t-ratio (probability)
Gross capital formation	0.202478	0.114886	1.762434
GDP	−0.190650	0.088763	−2.147860**
Fuel exports	0.110291	0.063487	1.737219
Energy imports	−0.081602	0.030319	−2.691462***
Constant	−3.635950	3.065030	−1.186269

The critical values are according to Elliot and Harackiewicz (1996) and **, ***denote 5% and 1% level of significance respectively

Table 8: Error correction model of the selected ARDL model (1, 1, 1, 0, 0)

Variables	Coefficients	Standard error	t-ratio (probability)
D (GKF)	0.26012	0.051468	5.0541**
D (GDP)	−0.049675	0.037195	−1.3355
D (FE)	0.058410	0.033285	1.7548
D (EI)	−0.043216	0.01305	−3.3113**
Coint Eq(−1)	0.123417	−4.2911**	−0.529597

The critical values are according to Elliot and Harackiewicz (1996) and **, ***denote 5% and 1% level of significance respectively. ARDL: Autoregressive distributed lag

Table 9: VAR granger-causality/block exogeneity wald tests

Null hypothesis	χ^2	P-value	Granger causality
GKF does not cause GRG	0.196224	0.6578	Unidirectional
GRG does not cause GKF	4.210329	0.0402**	GRG→GKF
GDP does not cause GRG	0.153660	0.6951	
GRG does not cause GDP	0.913075	0.3393	No causality
FE does not cause GRG	0.076437	0.7822	
GRG does not cause FE	0.061794	0.8037	No causality
EI does not cause GRG	0.010420	0.9187	Unidirectional
GRG does not cause EI	5.753657	0.0165**	GRG→EI

The critical values are according to Elliot and Harackiewicz (1996) and **, *** denote 5% and 1% level of significance respectively

the sense that it is negative and statistically significant at the 5% level. The coefficient (−0.529597) indicates that about 53% of the previous year's disequilibrium in green growth is corrected in the subsequent year. These results further reveal the speed at which the model converges to equilibrium. The magnitude of this coefficient implies that about 53% of any disequilibrium in green growth (GRG) is corrected by the independent variables within one period (one year); that is, the system will adjusts back to equilibrium at the speed of about 53%. The negative value of the ECM coefficient (−0.529597) confirms that there is disequilibrium in the short-run that will be corrected by the set of variables in the model in the long-run.

However, if the coefficient of ECM is greater than zero it means there is a surplus of the dependent variable which is the green growth variable. This implies that a reduction in the level of other variable estimates is required to restore equilibrium in the long-run. On the other hand, if the coefficient is less than zero, as shown in Table 8, there is a deficiency in green growth and an increase is required through the set of exogenous variables to restore it back to equilibrium in the long-run.

In an attempt to avoid biased results or misspecification from instability of the data, the methods of studying stability over time was considered, which included the CUSUM and CUSUMSQ tests. The CUSUM test or chart was employed to monitor changes in the series. This test was needed to confirm whether a structural change occurred within the period under review. However, it was necessary to conduct the stability tests to ascertain the effect of structural changes emanating from the transition from the apartheid period to the democratic elections period and the global financial crisis of 2008 on the data.

CUSUM and CUSUMSQ are tests for the stability of the long-term parameters of the model. Figures 1 and 2 illustrates that the long-term parameters are stable, since the plots is within the critical interval at the 5% level of significance. The study established co-integration and stability in the long-term parameters of the model. The co-integration or long-term relationship is an indication of the presence of causality among the variables which can be unidirectional or bidirectional. However, this study estimated the direction of causality among the variables by adopting the Toda-Yamamoto approach.

4.2. Analysis of Causality Test

The direction of causality is important from a policy point of view, as it will give policy makers or government the idea of aspects or direction of the policies that need more attention in order to achieve economic, social or environmental objectives. In the case of this study, the direction of causality will assist the researcher to identify the variable, within the policy context, that requires more attention for appropriate policy recommendations.

The Toda-Yamamoto approach also does not require pretesting, that is testing for co-integration between the variables, thereby avoiding the possibility of bias associated with unit root and co-integration (Rambaldi and Doran, 1996; Menyah and Wolde-Rufael, 2010). However, the unit root test and the co-integration tests performed in this study was not a pre-condition for the Toda-Yamamoto Granger-causality approach. The unit root and co-integration tests were employed to achieve the main focus of the study namely, evaluating the impact of energy policies on sustainable development in South Africa. The causality tests also formed part of the approaches to evaluate the impact of the green energy policies variable which is the dependent variable toward evaluating economic sustainability in South Africa. However, in order to investigate the direction of causality, each of the variables (green growth (GRG), gross capital formation (GKF), fuel export (FE), energy import (EI), and GDP was considered. The outcome of the Toda-Yamamoto approach to green growth and macroeconomic variables are presented in Table 9.

The direction of causality when each of the variables takes the position of the dependent variable in the investigation concerning economic sustainability adopting the Toda-Yamamoto Granger-causality approach is represented in the Table 9. The result

Figure 1: Cumulative sum of recursive residuals (CUSUM)

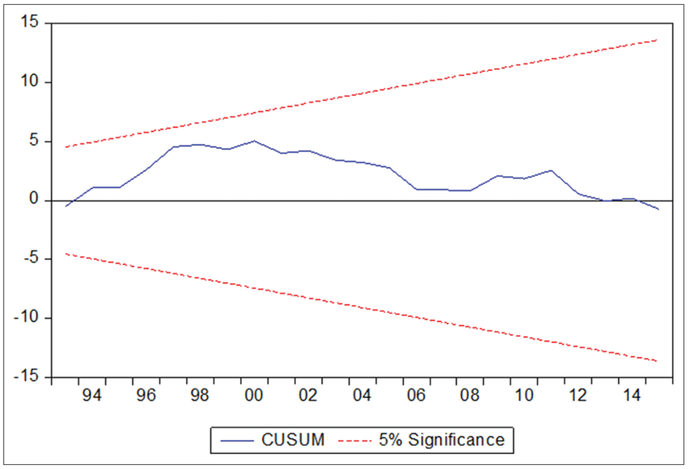


Figure 2: CUSUM squares (CUSUMSQ)

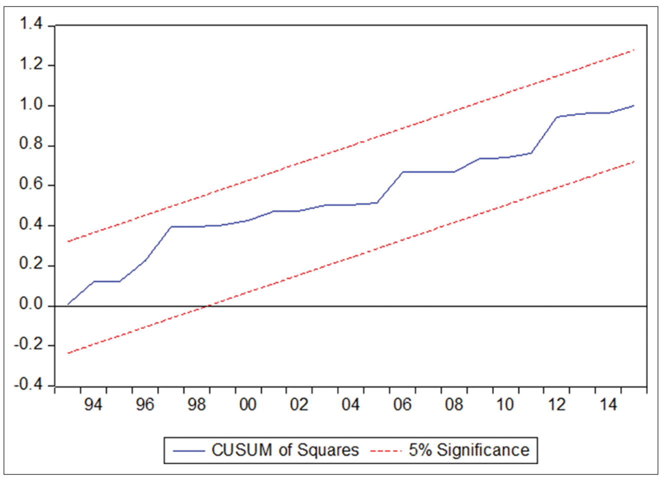
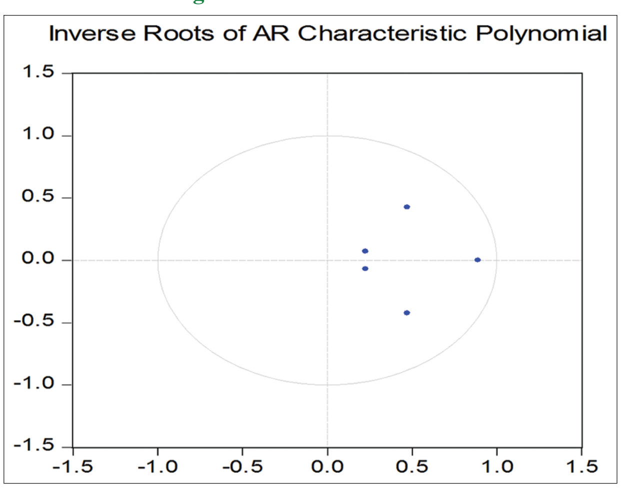


Figure 3: The unit circle test



reveals that the green growth variable being the dependent variable has unidirectional causal relationship with gross capital formation (GKF). Therefore, the causality runs from green energy consumption to gross capital formations without a feedback. This implies that there is an existence of a long-run causality running from green growth to gross capital formation without a feedback from gross capital formation to green growth. Consistent with the outcome of the causal relationship between green energy and gross capital formation, Khobai and Le Roux (2017) found causality running from renewable energy to capital formation.

In the Table 9 the causal relationship between the green growth variable (GRG) and the GDP reveals the absence of causality between GRG and GDP. This implies that, there is no presence of long-run causality between the green energy consumption variable and GDP; the outcome therefore, established the neutrality hypothesis. Consistent with the neutrality hypothesis Payne (2009) and Menegaki (2011), found the absence of causality between renewable energy and economic growth in the USA and Europe respectively. A study conducted by Bhattacharya et al. (2016) on top 38 renewable energy adopting countries including South Africa revealed that renewable energy is not a significant driver of economic growth in South Africa. The study by Sebri and Ben-Salha on Brazil, Russia, India, China and South Africa (BRICS), also established no positive or significant effect of RE on economic growth and vice versa.

Table 9 also shows the presence of unidirectional causality running from green energy to energy import without a feedback. The causal relationship between the green energy variable and fuel export shows no presence of causality. This means that fuel export did not spur green growth and vice versa within the study period. This section of this chapter also discusses the test of stability of the Toda-Yamamoto approach. The study employed the unit circle test, to evaluate the stability of the Toda-Yamamoto approach to Granger-causality tests.

The stability of the Toda-Yamamoto approach adopted in this study is illustrated in the Figure 3. The zeros fall within and not outside the unit circle which shows that the model is stable.

5. CONCLUSION

A long-run relationship between green growth and macroeconomic variables makes an important contribution in establishing the impact of green energy policies toward economic sustainability in South Africa. The study conducted the Philips Perron and Augmented Dickey Fuller unit root tests, and the ARDL approach to determine the effects of green growth and sustainable economy in Chapter Five. The ARDL bounds testing approach established a long-run relationship between green energy and economic variables (GDP, gross capital formation, energy import and fuel export) indicating the possibility of economic sustainability. The Toda-Yamamoto approach to Granger-causality also showed no bidirectional causal relationship with the variables even as causality runs from green growth to gross capital formation and energy import. Despite that South Africa is not only rich in green energy sources namely wind and sunshine.

South Africa has one of the highest solar radiations in the world with more than 2 500 hours of sunshine yearly with an average radiation level of between 4.5 and 6.5kWh/m^2 per day making it one of the top three countries in the world in this regard (DoE, 2015). The outcome of this study shows that the green energy sources can assist to ensure economic sustainability, but are yet to be adequately utilised to ensure economic sustainability in South Africa. The study, therefore emphasises the need to determine the necessary policy recommendations that can assist to achieve sustainable development and the targets of the various energy policies in South Africa. A general recommendation in this study will be to ensure a continued implementation of green growth policies in South Africa. A continued implementation of green growth policies will also assist to achieve some energy policies in South Africa which include: The New Growth Path: Accord 4-Green Economy Accord, which seeks to achieve a green economy and create five million green jobs by 2020 (EDD, 2011), and the National Development Plan (2012), aimed at ensuring available and competitively priced quality energy service to achieve social equity and environmental sustainability by 2030 (DoE, 2013). The green growth strategy could assist the country to achieve virtually all the sustainable development goals, which can be grouped under economic, social and environment.

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