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Impact of green energy policies on sustainable standards of living in South Africa: An ARDL and Toda-Yamamoto approach

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Abstract

This article investigates the long-term relationship between the Sustainable Development Goals (SDGs) of the United Nations and green energy in South Africa. It explains long-term impact of green energy policies of government on educational quality, agricultural development, unemployment rate and per capita gross domestic product. Autoregressive distributed lag-bound testing and Toda-Yamamoto approaches were applied to the data between 1994 and 2016. The results revealed a significant positive relationship between green energy, agricultural growth, and educational quality. Bidirectional causality between green energy policy variables, educational quality and agricultural growth are confirmed, while the impact on unemployment is yet to be established and the impact on wealth remains insignificant.

Keywords: renewable energy; green energy; standard of living; unemployment; GDP per capita; South Africa

JEL classification: I3, O4, J6, Q2, Q4

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1. Introduction

Fay (2012), Mboumboue and Njomo (2016) emphasised that green growth is the only vital strategy needed to set developing countries on the path of sustainable development through poverty alleviation and increased awareness of environmental issues. This is because a green economy has low levels of pollution, high levels of resource replenishment and productivity and is capable of enhancing standards of living in the rural and urban areas of the country. An increased adoption of renewable sources of energy (Solar, Wind, river drops, biomass, and ocean current) in different countries of the world remains a very important aspect of the sustainable development strategies (Malinowski, 2021). The situation of a high disease burden, food insecurity, malnutrition and infant mortality rate were part of the factors that hampered the full achievement of the millennium development goals in countries around the world (DST, 2013). The situation of electricity in South Africa is going in a diverse direction. Of the 634 million people without electricity in the sub-Saharan African countries (SSA), only eight million can be attributed to South Africa. Despite this record of electricity availability among the population of South Africa, the record from Afrobarometer states that only 5% of the people of South Africa claim not to have electricity problems (Sarkodie & Adams 2020).

Despite the relevance of clean energy or green energy in achieving improved quality of life, the literature has yet to fully explore the impact of renewable sources of energy consumption on the standard of living in developing countries, especially in South Africa. It is against this backdrop that the current study seeks to answer some salient questions like: what are the impacts of educational quality on green energy policies in South Africa? What are the effects of agricultural development on green energy policies in South Africa? Does the rate of unemployment have any effect on green energy policies in South Africa? The questions will be provided answers by investigating the long-term relationships between renewable energy consumption, unemployment rate, income (GDP per capita), educational quality and agricultural growth in South Africa. In line with these investigations, there are some energy policies in South Africa to achieve these long-term targets like the commitment to the full and integrated implementation of Sustainable Development Goals (SDGs) 2030 is ongoing and in line with the National Development Plan (NDP) of ensuring inclusive economic growth, elimination of poverty, and reduction of inequality by the same 2030 in South Africa remains important. This study contributes to and guides policies that may promote the achievement of the development agendas before 2030.

The rest of this article is structured as follows: Section 2 discusses the literature, section 3 presents the model and methodology, section 4 presents the data and empirical findings of the study, and Section 5 provides the conclusion.

2. Brief literature review

The study of the relationship between green energy and the standards of living, employment and health has been the object of theoretical and empirical review.

The endogenous growth model is a good theory to analyse the relationship among the variables as it shows how long-run economic growth is a build-up of economic activities that generates new technological knowledge. This simply implies that endogenous growth is a long-term economic growth and the level of growth is generally determined by factors that are within or internal to an economic system. The endogenous growth theory is different from the neoclassical growth model as it makes available the medium through which the rate of technological progress and the rate of long-run economic growth can be determined by economic factors. It can be seen from the Schumpeterian view that technological progress is as a result of innovation which can be in the form of new products, processes or even markets. Endogenous growth theory may also be seen as long-term growth resulting from various economic activities or factors from within (Romer, 1994; Aghion, et al. 1998). Kahn (1995) states that endogenous growth theory is in line with the sustainable development growth theory. The theory views economic sustainability from a growth, resource allocation and consumption perspective. It assumes natural resources to be infinite and that poor or the less privileged are affected by growth in the economy. In other words, the record of growth in the economy should include the poor. In order to determine how some internal factor help to determine the rate of consumption of green energy, some empirical investigations have been carried out.

Obeng et al. (2008) investigated the relationship between electrification in rural areas in Ghana using solar photovoltaic electricity (PV) and the poverty level among households. Solar photovoltaic was the source of energy, while the poverty level was also assessed using economic, social, and environmental indicators from questionnaires. The varying distribution ascertained the energy-poverty ratio in the electrified and non-electrified households. They adopted principal component analysis (PCA) and developed an energy-poverty index (EPIS). An increasing energy-poverty index score (EPIS) was accompanied by a linear increase in three significant indicators, which explained the variation in the EPIS. These three indicators are monthly savings on lighting ($r^2 = 0.214$), the number of children available to sit around lighting ($r^2 = 0.388$) and the amount spent on lighting or acquiring electricity systems ($r^2 = 0.261$). Inversely, it was noticed that EPIS decreased linearly as

monthly costs of kerosene, candles and dry-cell batteries rose. The study found that an increase in expenditure on kerosene, candles and dry-cell batteries affected savings that would be diverted to other energy delivery systems that have a high tendency to increase EPIS.

Sadorsky (2009) investigated the possible relationship between per capita renewable energy consumption and real income per capita in emerging economies from 2005 to 2030 by adopting panel co-integration estimates. The results presented a significant and positive relationship between per capita income and per capita renewable energy consumption. This implies that an increase in the per capita income would result in an increase in per capita renewable energy consumption. Payne (2009) investigated the direction of causality in the USA, collecting annual data from 1949 to 2006. The Toda-Yamamoto approach to Granger causality revealed the neutrality hypothesis (absence of causality) between renewable energy or non-renewable energy and real GDP.

Wei et al. (2010) probed the American (USA) employment model in the power sector from 2009 to 2030. The study applied data from fifteen employment studies related to renewable energy, energy efficiency, carbon capture and storage, nuclear power, coal, and natural gas utilising a descriptive-analytical model for a meta-analysis of these fifteen, adopting a normalisation approach to the estimation of average employment per unit of energy produced over the lifespan of a production unit. The study established that the utilisation of renewable energy, contributed to more jobs than fossil fuel per unit of energy. The result varies between technologies and the type of activities, such as extraction or manufacturing.

Apergis and Payne (2010) investigated the causal relationship between renewable energy consumption labour force, and real gross fixed capital formation, with the adoption of heterogeneous panel co-integration tests for 13 countries within Eurasia between 1992 and 2007. The study revealed a long-term relationship between renewable energy, the labour force and real gross fixed capital formation. The outcome of the heterogeneous co-integration showed a long-term relationship between the variables. The outcome of the error correction models also showed bidirectional causality running from renewable energy to economic growth and a feedback effect in both the short- and long-term periods. Thiam (2011) applied the lifecycle cost approach. He considered the assessment of environmental externalities and investigated the impact of renewable energy on poverty alleviation in Senegal. It revealed that solar renewable energy increases people's standard of living in remote rural areas where there is yet to be a presence of grid-grid connections. A study by Apergis and Payne (2012) adopted a multivariate framework of data for 80 countries between 1990 and 2007 to ascertain the impact of renewable energy on non-renewable energy, labour force, and economic growth by utilising the Pedroni (1999, 2004) heterogeneous panel co-integration test. The study established a long-term relationship and a positive and significant relationship among the variables and a positive bidirectional relationship running between renewable energy and economic growth, non-renewable energy and economic growth and renewable and non-renewable energy both in the long- and short-term period.

Lin and Moubarak (2014) estimated the relationship between renewable energy consumption and economic growth, labour, and CO₂ emissions in China between 1977 and 2011. The ARDL and Johansen co-integration techniques were adopted to study the long-term relationship among the variables and the Granger-causality test to determine the direction of causality. The study showed a bidirectional causality running from renewable energy to economic growth with a feedback effect and a positive impact of labour on renewable energy consumption. There was, however, an absence of long-term or short-term causality between renewable energy and CO₂ emissions.

Shoaib and Ariaratnam (2016) applied a two-phase approach to study the impact of community-based renewable energy (CRE) on the economic and social lives in towns and communities in Afghanistan by assessing existing literature and technologies and conducting a comprehensive survey. They found a modest economic impact of CRE with limited support for business activities and job creation. They also found the relative importance of CRE in providing a sustainable supply of energy

to these towns and communities.

Osiolo (2016) used regression and input-output econometric techniques to study how renewable energy may impact employment and economic growth in Kenya. It found a positive relationship between renewable energy, employment, and economic growth. Hernik, Rutkowska and Noszczyk (2016) adopted Spearman's rank correlation to determine the strength and direction of a relationship that exists between renewable energy sources (RES) and some socio-economic variables, for example, the surface area of agricultural land, unemployment rate, the surface area of land under surface flowing water, population density, number of unemployed people registered for over a year, total EU fund acquired per capita income, and surface area of wasteland in all districts of Świętokrzyskie Voivodeship in Poland. The study found that only per capita income had a statistically significant impact on renewable energy sources as there was no correlation between RES and the other variables.

Simionescu, Bilan, Krajňáková, Streimikiene and Gędek (2019) adopted the panel data models to examine the possible relationship between renewable energy sources and real GDP per capita in European Union countries, except for Luxembourg, between 2007 and 2017. The study found a positive and statistically significant relationship between GDP's per capita and renewable energy. The study also did not find any causality between GDP per capita and renewable energy sources for the European Union countries. Fang (2011) uses the multivariate ordinary least square (OLS) technique to examine the impact of renewable energy consumption on the economic welfare of China between 1978 and 2008. The study showed that an increase in renewable energy consumption (REC) of one per cent will have a 0.162% effect, a 0.444% increase in the GDP capita and annual per capita income of rural households and a 0.368% increase in per capita annual income of urban households. Their results do, however, show an insignificant impact of renewable energy consumption on economic welfare.

Getie (2020) adopted the direct interview approach to collect data from local and urban communities in Ethiopia in addition to the data from the central statistical agency and adopted the statistical data analysis to determine the effect of energy poverty on the standards of living of households, education, health, and agricultural development. The study found poor access to sustainable electricity among the people of Ethiopia and that available electricity had no significant impact on the living standards of the people, educational system, agricultural and health system.

Using panel co-integration, fully modified ordinary least squares, dynamic ordinary least square, and Pedroni panel cointegration techniques to estimate the relationships between green investments (PICE), GDP per capita, renewable energy (RE), and greenhouse gas emissions (GHG) among EU countries between 2008 to 2016, Lyeonov et al. (2019) found co-integration between per capita economic income, total final energy, green gas emissions, renewable energy, and final energy consumption. They also found that the green investment could increase GDP per capita by 6.4%, reduce GHG by 3.08% and raise renewable energy as part of the total final energy by 5.6%.

Ntanos et al. (2018) investigated the impact of renewable energy on the quality of life of 400 urban residents among African people living in Greece by utilising the principal components analysis in conjunction with the Logit Regression. The datasets were also gathered from the views on the different aspects of renewable energy sources. The results show that the residents have good knowledge of the relevance of renewable energy on the quality of life. Simionescu et al. (2019) applied a panel data model to study the impact of the share of renewable energy sources in the total energy of some European Union (EU) countries between 2007 and 2017. They found a positive and low effect of renewable energy on per capita income among the EU countries, except for Luxembourg, which showed outlier values with per capita GDP. They did not find any causality between renewable energy and per capita GDP.

Cheng et al. (2021) investigated the research concerns of the relationship between poverty alleviation (RE-PA) practices, sustainable development goals (SDGs), and renewable energy globally. The study finds that the country's energy policies, SDGs perspectives of economic, social, and

environment are the three main research concerns for RE-PA.

Masron, et al. (2021) adopt the GMM estimator to evaluate the impact of renewable energy in reducing the effect of poverty on the destruction of the environment among developing countries for the period 2001 and 014. The study found a negative relationship between renewable energy and environmental destruction from poverty. This outcome implies that renewable energy has the tendency to reduce environmental destruction as a result of the level of poverty among developing countries.

The above empirical literature on the impact of renewable energy on educational quality, agricultural development, unemployment rate and per capita income, shows that this aspect of the literature is yet to be fully explored for African countries, especially South Africa. Literature has, however, exhibited a level of divergence with some studies showing a positive relationship between renewable energy and real GDP per capita, and unemployment rates by adopting empirical techniques, such as the correlation techniques, ARDL and Johansen co-integration techniques (Thiam, 2011; Wei et al., 2010; Inglesi-Lotz, 2016; Sadorsky, 2009). These findings from the literature align with the endogenous growth theory since in the long run there is a positive link between factors like renewable energy and GDP per capita (Simionescu, Bilan, Krajňáková, Streimikiene & Gędek, 2019). The findings imply that the dependent or the endogenous variable was positively affected by one or more independent variables. On the other hand, the endogenous growth theory was not supported by some results, for example, after adopting Spearman's rank correlation technique, Rutkowska and Noszczyk, (2016) did not establish any correlation between renewable energy sources, unemployment rate, total Eur fundsn Union fund acquired, the surface area of agricultural land, population density, and surface area of land under flowing water in all districts of Świętokrzyskie Voivodeship in Poland. Fang (2011) also found an insignificant impact of renewable energy consumption on economic welfare.

Based on these findings in the literature, the dependent and explanatory variables were adopted from the Sustainable Development Goals (SDGs) agenda. The SDGs related to no poverty (Goal 1) and zero hunger (Goal 2) are represented by agricultural growth, while quality education (Goal 4) is reflected through educational quality. Affordable and clean energy (Goal 7) is associated with green energy, and reduced inequality (Goal 10) is represented by gross domestic product per capita. The Autoregressive Distributed Lag bound testing and the Toda-Yamamoto approaches were adopted to check the long-run relationship and direction of causality, respectively, between green energy and educational quality, agricultural development, unemployment rate, and gross domestic product per capita.

3. Model and methodology

The variables in this study were based on the sustainable development goals, which are in line with some South African green energy and social equity policies and align directly with the theoretical underpinnings of endogenous growth theory in this study. We adopt the Autoregressive Distributed Lag bound testing and the Toda-Yamamoto approaches to check the long-run relationship and direction of causality respectively between green energy and educational quality, agricultural development, unemployment rate, and gross domestic product per capita.

Equation (1) shows the relationship between green energy (GE) as the dependent variable and explanatory variables, educational quality (EQ), agricultural development (AG), unemployment rate (UR), and gross domestic product per capita (GDPPK). The equation is best explained with the endogenous growth theory as the dependent variable, where the green energy variable is greatly determined by external economic factors, which are the independent or explanatory variables.

$$GE = f(GDPPK_t, EQ_t, AG_t, UR_t) \quad (1)$$

Green energy is proxied by alternative and nuclear energy at time t. alternative and nuclear energy is the source of energy that is produced without the burning of fossil fuels which has high

carbon dioxide Educational quality is proxied by government expenditure on education according to World Bank data is the portion of GDP that is expended on education. It is supported by Goal 4 of the Sustainable Development Goals (United Nations, 2016), and one of the medium- and long-term targets of the South African Green Economy Modelling (SAGEM) (UNEP, 2013). Agricultural development represents agricultural development at value added (annual percentage growth). It simply refers to output of the agricultural sector in the country as part of GDP. Agricultural development aligns with Goal 2 and also forms part of the SAGEM programmes (UNEP, 2013). Unemployment is represented by the unemployment total which is the number of unemployed as a percentage of the total labour force. The need to reduce the level of unemployment supports Goal 8 of SDGs. The adoption of some of the variables utilised in this study also follows previous studies, for example, Simionescu, Bilan, Kraňáková, Streimikiene and Gędek (2019), Fang (2011), and Hernik, Rutkowska and Noszczyk (2016).

The dependent variable and the explanatory variables chosen in the model above are in line with that of Ackah and Kizys (2015), Lin and Moubarak (2014) and align with the analysis of Fay (2012). GE is green energy policies at time t , represented by alternative and nuclear energy

The expression in equation (1) can explicitly be set as:

$$GE = \alpha_1 + \delta_1 GDPPK_t + \lambda_1 EQ_t + \nu_1 AG_t + \Omega_1 UR_t \quad (2)$$

The stochastic form of this equation states:

$$GE_t = \alpha_1 + \delta_1 GDPPK_t + \lambda_1 EQ_t + \nu_1 AG_t + \Omega_1 UR_t + \epsilon_t \quad (3)$$

3.1 Stationarity test framework

Equation (3) is usually applied to ensure that the time-series data is examined appropriately. Maddala and Lahiri (2009) stated that from a theoretical point of view a collection of random variables X_{it} . If it is a discrete variable, it is denoted as X_t and if it is a random variable, it is denoted as $X(t)$. Harver (1990) suggested that a paradigm known with the time-series is the assumption that a series can be made stationary by differencing or detrending the data.

The unit root test is required for a time-series data analysis as a nonstationary regressor makes several empirical results invalid and this might demand special attention. Through simulations, Granger (1996) determined that the non-stationary regression F-statistic calculated does not follow a standard distribution. Under the null hypothesis of no causality, the non-standard distribution comes with sub-standard right-forward shifts. The unit root is, therefore, applied to determine the presence of a stochastic trend in the time-series data. The Dickey-Fuller (1981) test usually examines non-stationarity or the presence of unit roots in the time-series data (Chtioui, 2012). The present study will, therefore, use the augmented Dickey-Fuller and Philips Perron tests to confirm the presence of unit roots in the time-series data.

3.2 The Bounds testing approach

Existing research utilises the ARDL Bounds test approach to co-integration to determine the relationship between energy consumption and economic development (Shahbaz et al., 2013; Ogundipe, Akinyemi and Ogundipe, 2016). The explanatory variables were adopted from the SDGs agenda. The models utilised in the present study are ARDL models to illustrate the relationship between the green energy variables and the educational quality, agricultural development, unemployment rate, and gross domestic product per capita. The adoption of the ARDL approach to co-integration will assist in the determination of the adoption of green energy policies that will have a long-term impact on the educational quality, agricultural development, unemployment rate and per capita GDP. To summarise: It will assist in determining whether the adoption of green energy policies by the government will enhance the achievement of sustainable development goals.

The ARDL approach is preferred to other cointegration techniques, such as Engle and Granger's causality, and Johansen and Joselius for some specific reasons, such as that the ARDL technique may be applied without considering the unit root pretesting or classifying the data into $I(0)$ or $I(1)$, unlike other techniques. The ARDL cointegration technique is preferable when the variables are integrated of order $I(0)$, or $I(1)$ or a combination of both, but not $I(2)$, as the technique will not yield the intended result or will crash as a result of the presence of $I(2)$ in the trend. To avoid unpredicted results or model misspecifications that will yield no statistical importance, it is, therefore, always important to test for unit roots. Another advantage of the ARDL technique over other techniques is that it can identify the cointegrating vector amid several cointegrating vectors (Gujarati, 2019; Nkoro & Uko, 2016).

The parameters $\beta, \delta, \lambda, \Omega$ and v in the equations below are the short-term dynamic co-efficient, while the η_I where the $I = 1, 2, 3, 4, 5, 6$ represent the long-term multipliers of the ARDL model. Utilising the ARDL model above, this study will first examine the null hypothesis of co-integration being absent or no co-integration, $H_0 : \eta_1 = \eta_2 = \eta_3 = \eta_4 = 0$ against the alternative by adopting the F-test statistics.

$$\begin{aligned} \Delta GE_t = & \alpha_1 + \sum_{i=1}^p \beta_1 \Delta GE_{t-1} + \sum_{i=0}^p \delta_1 \Delta GDPPK_{t-1} + \sum_{i=0}^p \lambda_1 \Delta EQ_{t-1} \\ & + \sum_{i=0}^p v_1 \Delta AG_{t-1} + \sum_{i=0}^p \Omega_1 \Delta UR_{t-1} + \eta_{1Y} GE_{t-1} \\ & + \eta_{2Y} GDPPK_{t-1} + \eta_{3Y} EQ_{t-1} + \eta_{4Y} AG_{t-1} + \eta_{5Y} UR_{t-1} + \epsilon_t \end{aligned} \quad (4a)$$

$$\begin{aligned} \Delta GDPPK_t = & \alpha_1 + \sum_{i=0}^p \beta_2 \Delta GE_{t-1} + \sum_{i=1}^p \delta_2 \Delta GDPPK_{t-1} + \sum_{i=0}^p \lambda_2 \Delta EQ_{t-1} \\ & + \sum_{i=0}^p \Omega_2 \Delta UR_{t-1} + \eta_{1N} GE_{t-1} + \eta_{2N} GDPPK_{t-1} \\ & + \eta_{3N} EQ_{t-1} + \eta_{4N} AG_{t-1} + \eta_{5N} UR_{t-1} + \epsilon_{2t} \end{aligned} \quad (4b)$$

$$\begin{aligned} \Delta EQ_t = & \alpha_3 + \sum_{i=0}^p \beta_3 \Delta GE_{t-1} + \sum_{i=0}^p \delta_3 \Delta GDPPK_{t-1} + \sum_{i=1}^p \lambda_3 \Delta EQ_{t-1} \\ & + \sum_{i=0}^p v_3 \Delta AG_{t-1} + \sum_{i=0}^p \Omega_3 \Delta UR_{t-1} + \eta_{1R} GE_{t-1} \\ & + \eta_{2R} GDPPK_{t-1} + \eta_{3R} EQ_{t-1} + \eta_{4R} AG_{t-1} + \eta_{5R} UR_{t-1} \\ & + \epsilon_{3t} \end{aligned} \quad (4c)$$

$$\begin{aligned}
\Delta AG_t = & \alpha_5 + \sum_{i=0}^p \beta_5 \Delta GE_{t-1} + \sum_{i=0}^p \delta_5 \Delta GDPPK_{t-1} + \sum_{i=0}^p \lambda_5 \Delta EQ_{t-1} \\
& + \sum_{i=1}^p v_5 \Delta AG_{t-1} + \sum_{i=0}^p \Omega_5 \Delta UR_{t-1} + \eta_{1T} GE_{t-1} + \eta_{2T} GDPPK_{t-1} \\
& + \eta_{3T} EQ_{t-1} + \eta_{4T} AG_{t-1} + \eta_{5T} UR_{t-1} + \epsilon_4
\end{aligned} \tag{4d}$$

$$\begin{aligned}
\Delta UR_t = & \alpha_5 + \sum_{i=0}^p \beta_6 \Delta GE_{t-1} + \sum_{i=0}^p \delta_6 \Delta GDPPK_{t-1} + \sum_{i=0}^p \lambda_6 \Delta EQ_{t-1} \\
& + \sum_{i=1}^p v_6 \Delta AG_{t-1} + \eta_{1Q} GE_{t-1} + \eta_{2Q} GDPPK_{t-1} + \eta_{3Q} EQ_{t-1} \\
& + \eta_{4Q} AG_{t-1} + \eta_{5Q} UR_{t-1} + \epsilon_{6t}
\end{aligned} \tag{4e}$$

3.3 Causality test framework

The optimal econometric method to examine the causal relationship between two variables is the Granger-causality test (1996). The approach involves estimating the simple vector auto-regressions (VAR) and can determine the direction of cause and effect between related variables. The Granger-causality technique is therefore used to determine the direction of causality in the current study.

The VAR model captures the relationship between, for example, GE and GDPPK and how both variables affect each other with some distributive lags and affect one another. In other words, the model shows how the GE causes GDPPK and how GDPPK causes GE. Therefore, there exists bidirectional feedback between the variables that are usually captured by the VAR model irrespective of the independent relationship between the variables. The feedback can, therefore, be a directional causality, unidirectional causality, a neutral or even independent effect among the variables.

An adopted Toda and Yamamoto (1995) approach (TY) to evaluate for causality was utilised in this section. The Toda-Yamamoto approach to causality avoids the problems identified with traditional causality tests like the Granger-causality test. The Toda-Yamamoto approach to causality is not associated with the need to determine stationarity or co-integration between series. The Toda-Yamamoto approach can, therefore, be applied whether a series is $I(0)$, $I(1)$ or even $I(2)$, or the series may not be co-integrated of any arbitrary order (Rambaldi & Doran, 1996; Menyah & Wolde-Rufael, 2010). The Toda-Yamamoto approach is superior to the conventional Granger-causality approach because it is not affected by any possible bias associated with unit roots 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, despite 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. The TY approach, therefore, takes long-term information that is usually ignored by taking the first differencing of variables and pre-whitening, into consideration (Kum et al., 2012; Menyah & Wolde-Rufael 2010).

Consistent with studies by 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 four lags ($k = 3$ and $d_{max} = 1$). The current research estimated the following system of equations:

$$\begin{pmatrix} GRG_t \\ GDPPK_t \\ EQ_t \\ AG_t \\ UR_t \end{pmatrix} = A_0 + A_1 \begin{pmatrix} GRG_{t-1} \\ GDPPK_{t-1} \\ EQ_{t-1} \\ AG_{t-1} \\ UR_{t-1} \end{pmatrix} + A_2 \begin{pmatrix} GRG_{t-2} \\ GDPPK_{t-2} \\ EQ_{t-2} \\ AG_{t-2} \\ UR_{t-2} \end{pmatrix} + A_3 \begin{pmatrix} GRG_{t-3} \\ GDPPK_{t-3} \\ EQ_{t-3} \\ AG_{t-3} \\ UR_{t-3} \end{pmatrix} + A_4 \begin{pmatrix} GRG_{t-4} \\ GDPPK_{t-4} \\ EQ_{t-4} \\ AG_{t-4} \\ UR_{t-4} \end{pmatrix} + A_5 \begin{pmatrix} GRG_{t-t} \\ GDPPK_t \\ EQ_t \\ AG_t \\ UR_t \end{pmatrix} \quad (5)$$

The Equation 5 shows that A_1, A_2, A_3, A_4 , subscription are 6x6 matrices and the coefficient of A_0 as the representative of the 6x1 identity matrix, with ϵ as 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 per capita ($GDPPK_t$). This will be achieved using the following hypothesis: $H_0 = \alpha_{12}^1 = \alpha_{12}^2 = \alpha_{12}^3 = 0$. However, $\alpha_{12}^1, \alpha_{12}^2$ and α_{12}^3 represent the coefficient of the GDP variable in the first equation of the system presented in equation 5. On the other hand, the study can also evaluate the non-causality from ($GDPPK_t$) to (GRG_t) in the following hypothesis: $H_0 = \alpha_{21}^1 = \alpha_{21}^2 = \alpha_{21}^3 = 0$. Therefore, $\alpha_{21}^1, \alpha_{21}^2$ and α_{21}^3 are also coefficients of green energy (GE_t) equation presented in equation 5. The test between green energy (GE_t) and other explanatory variables such as gross domestic product per capita ($GDPPK_t$), educational quality (EQ_t), agricultural growth (AG_t) and unemployment rate (UR_t) is evaluated.

3.4 Stability test

The stability of the models is assessed and determined by adopting the Toda-Yamamoto approach to evaluate the long-term direction of causality between 1994 and 2016. The study further applies the unit circle and serial correlation Lagrange multiplier (LM) tests. This will confirm whether the educational quality, agricultural development, unemployment rate and per capita income are reasonably explained by the green economic variable.

The study conducted diagnostic tests to determine the presence of econometric issues such as multicollinearity, heteroscedasticity, misspecification of the model, and autocorrelation, and to check the normality of the time series data.

Table 1. Diagnostic tests for optimal lag selected

Serial	Tests statistics	LM version	F version
A	Serial correlation	CHSQ (1)= 2.488 (0.2881)	F(2,9)= 0.288 (0.5669)
B	Misspecification Tests	CHSQ (10)=1.065 (0.3121)	F (1,10) =1.133 (0.3121)
C	Normality	CHSQ (9)= 0.177 (0.9165)	SD=0.0966
D	Heteroscedasticity	CHSQ (9) = 8.188 (0.5153)	F(9,11)= 0.781(0.6389)

Note: A: The application of the Breusch-Godfrey serial correlation LM test. B: Ramsey's RESET techniques adopting the sum of the squared of the fitted lines, C: Based on the Breusch-Pagan Godfrey of the observed R2, D: Based on the Jarque-Bera (JB) test of skewness and kurtosis of residuals.

4. Empirical research findings

The co-integration test was conducted to determine whether there is a long-term relationship between green energy policies and educational quality, agricultural development, unemployment rate and per capita gross domestic product. The ARDL procedure was adopted to evaluate the long-term relationship. Application of the ARDL approach is possible since the series are integrated of both levels 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 was conducted, based on findings by Pesaran et al. (2001).

The lag length selection criteria suggested a maximum of two lags for the ARDL model in this study. To implement the information criteria for selecting the lag-length in a time-effect way, the lag structure was estimated. The appropriate lag length was determined by using one or more of the Akaike information criterion (AIC), Schwarz information criterion (SIC) and Hannan-Quinn information criterion (HQ). The results suggest a maximum of two lags for the ARDL based on AIC. The estimation of the long-term relationship between the variables is important to confirm whether the relationship between the dependent and explanatory variables is sustainable over the long term.

Table 2. ARDL bounds test

Test statistic	Value	K
F-statistic	8.097	4
Critical value bounds		
Significance	I(0) Bound	I(1) Bound
10%	2.45	3.52
5%	2.86	4.01
2.50%	3.25	4.49
1%	3.74	5.06

Source: Researchers' analysis

The results in Table 2 reveal the value of the F-statistic as 8.096628 at four degrees of freedom and the critical lower and upper bounds at 5% are 2.86 and 4.01, respectively, consistent with Pesaran et al. (2001).

As the value of the F-statistic exceeded the upper bound at the 5% significance level at 8.096628, this study found evidence of a long-term relationship between GE (green energy) and the set of other independent variables such as gross domestic product per capita (GDPPK), educational quality (EQ), agricultural development (AG) and the unemployment rate (UR). The hypothesis of no co-integration is, therefore, rejected. Consistent with this study, Ackah and Kizys (2015) found co-integration between the renewable variable and gross domestic product per capita, labour force and human capital. Because of the sensitivity of the time-series data and the method of investigation, the study conducted a diagnostic analysis of the models.

Table 3 illustrates a long-term relationship between the dependent variable and the explanatory variables. It shows a positive and statistically significant relationship between the green energy variable and both agricultural development and educational quality. This implies that a change in the green energy policy within the review period can be attributed to significant changes in agricultural development and educational quality in South Africa. Developing agriculture and improving the quality of education in countries form part of the sustainable development agenda. This also forms an essential element of the renewable energy policy of the South African authorities as designed by the Department of Minerals and Energy and other relevant institutions in the country.

Table 3. Long-term results

Variable	Coefficient	Std. error	t-statistic	Probability
UR	0.044	0.017	2.653	0.023
GDPPK	-0.0004	0.017	-0.024	0.982
EQ	0.372	0.0713	5.214	0.0003
AG	0.435	0.047	9.346	0.0000
C	1.455	1.281	1.135	0.339

A negative and statistically insignificant relationship also exists between the green energy consumption variable and gross domestic product per capita (GDPPK). The negative and insignificant relationship between green energy consumption and gross domestic product per capita is an indication that living standards have not yet improved to such an extent that it has a significant impact on higher consumption of green energy in South Africa. It suggests that programs and policies to improve the standards of living by supplying more electricity to households should be oriented towards green energy adoption in South Africa.

This is also not in line with the endogenous growth theory that views that the rate of growth as dependent factors within the system. A similar study by Ogundipe et al. (2016) established a negative relationship between energy consumption and economic development. The long-term relationship between the green energy variable and both educational quality and the unemployment rate shows a significant and positive relationship. The result indicates that policies such as the New Growth Path: Accord 4 aimed at providing 5 million jobs by 2020 by promoting a green economy in South Africa have been impactful. This implies that as the country tries to improve the educational quality and living standard, it has resulted in increased consumption. The positive relationship that exist between green energy consumption and unemployment implies that even as there is increase in the consumption of green energy, there is still increase in the level of unemployment as the people without still don't have funds to access this source of electricity.

4.1 Error correction mechanism (ECM)

This study established the long-term stochastic trend and co-integration among the green energy consumption variable and its regressors, which include per capita income (GDPPK), educational quality (EQ), agricultural development (AG) and the unemployment rate (UR). The study also investigated the error correction mechanism of the variables to evaluate both the short-term and long-term effects of the time-series data for each of the variables. A summary of the ECM applied to estimate the speed at which the green energy variable returns to equilibrium after a change in any of the explanatory variables is presented in Table 4.

Table 4. Error correction mechanism

Dependent variable: GE				
Selected model: ARDL(1, 0, 0, 2, 2): Error correction results				
Variable	Coefficient	Std. error	t-statistic	Probability
D(UR)	0.064	0.027	2.403	0.035
D(GDPPK)	-0.0018	0.025	-0.024	0.982
D(EQ)	-0.049	0.163	-0.303	0.768
D(EQ(-1))	-0.362	0.247	-1.465	0.171
D(AG)	-0.191	0.232	-0.825	0.427
D(AG(-1))	-0.17	0.161	-1.055	0.314
CointEq(-1)	-1.441	0.25	-5.773	0.0001

Source: Researchers' analysis

Table 4 illustrates the dynamic adjustment of disequilibrium in the short term. The error coefficient mechanism coefficient is well defined since it is negatively and statistically significant at the 5% level of confidence. The coefficient is minus 1.441134, which illustrates that the system corrected its previous period disequilibrium at a speed of 144% and also indicates the high speed at which the model converges to a long-term equilibrium steady state. The magnitude of this coefficient implies that about 144% of any disequilibrium in green energy (GE) is corrected by the independent variables within one period (one year).

The coefficient should have a negative sign and when the ECM coefficient is positive, it means that there is a surplus of the dependent variable. However, a surplus of green energy adoption will require a reduction in the level of other variables to restore it to equilibrium in the long term. Based on the results given in Table 4, the coefficient is negative, implying that green energy is deficient, and an increase is required through the set of exogenous variables to restore equilibrium in the long term. The high negative coefficient and statistical significance of the ECM in this study mean that there will be a rapid rate of correction of previous period disequilibrium at a speed of 144%.

The co-integration and error correction mechanism has now been identified and analysed. It is, however, necessary to determine whether the variables are stable. That will ensure restoration back to equilibrium, as explained by the ECM. Narayan and Smith (2005) stated that a particular issue of the estimated time-series regression model is the possibility of parameters changing over time, which can lead to misspecification and possible biased results. The present study, therefore, employed the cumulative sum of recursive residuals (CUSUM) and CUSUM squared (CUSUMSQ) to avoid the possible instability of the parameters.

4.2 Stability test

Figures 1 and 2 illustrate that the null hypothesis of the CUSUM and CUSUMSQ tests cannot be rejected since the plots fall within red dotted lines of the critical limits. The null hypothesis of CUSUM and CUSUMSQ states that the regression equations are correctly specified and cannot be rejected. The short- and long-term estimates in this study are, therefore, reliable.

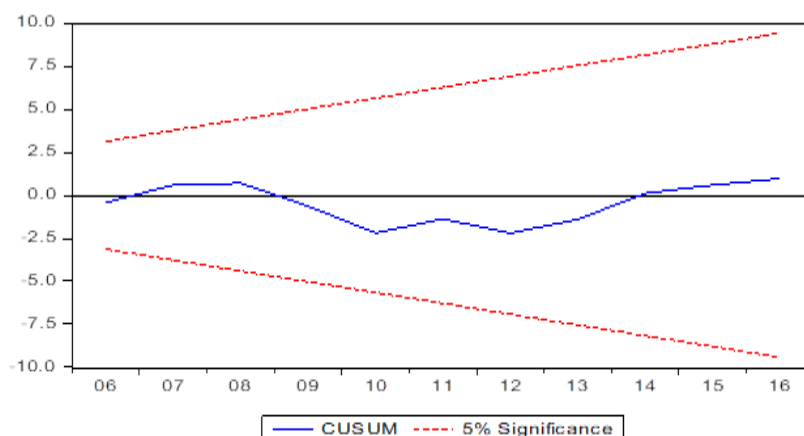
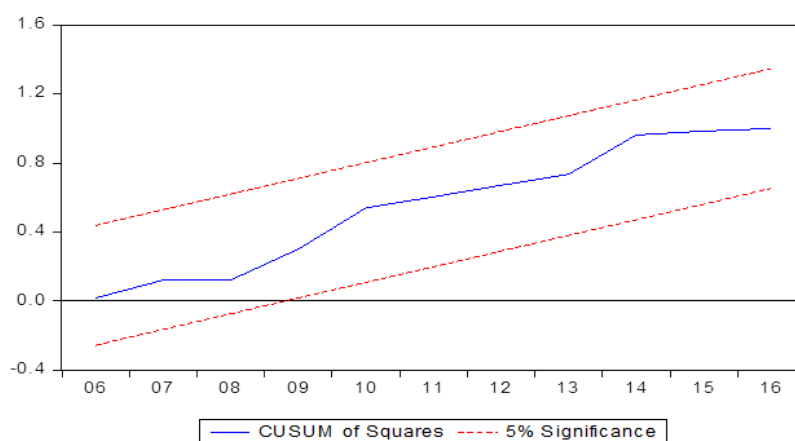


Figure 1. The cumulative sum of squares (CUSUM)



Source: Researchers' analysis

Figure 2. The cumulative sum of square recursive residuals square (CUSUMSQ)

4.3 Toda-Yamamoto causality tests

The presence of co-integration and long-term relationships was found between the green energy variable and educational quality, agricultural development, unemployment rate, and gross domestic product per capita such as gross domestic product per capita (GDPPK), educational quality (EQ), agricultural development (AG), and unemployment rate (UR). Causality is the ability of a variable to predict or cause another variable to change. It is, therefore, either gross domestic product per capita (GDPPK) that causes the green energy consumption variable (GE) to change, or GE causes GDPPK to change or both causing each other to change. If only GDPPK causes to change and not vice versa, then it is a unidirectional causality. On the other hand, if GE is causing GDPPK to change and GDP causing GE to change, then bidirectional causality exists.

From a policy point of view, the direction of causality is important as it provides policymakers or government with insight regarding the parts or direction of policies that require special attention to achieve economic, social, or environmental objectives. In the present study, the direction of causality assists the researchers to identify the variable, within the policy context, which requires more attention to suggest appropriate policy recommendations.

The Toda-Yamamoto (TY) approach to Granger-causality testing was utilised in the present study to assess the direction of causality among the variables. These peculiar features of the TY approach compared to the conventional methods of causality testing make it appropriate for this study (Wolde-Rufael, 2005). The Toda-Yamamoto approach also does not require pretesting for co-integration between the variables, thereby avoiding the possibility of bias associated with unit roots and co-integration (Rambaldi & Doran, 1996; Wolde-Rufael, 2010).

The unit root and the co-integration tests conducted in this study are not a pre-condition for the Toda-Yamamoto Granger-causality approach. These tests were employed to achieve the main focus of the study, which is to evaluate the impact of green energy policies on standards of living or social sustainability in South Africa. The result of the Toda-Yamamoto approach to green energy and educational quality, agricultural development, unemployment rate and per capita income are presented in Table 5. To investigate the direction of causality between each of the variables, the Toda-Yamamoto Granger-causality test was employed.

Table 5. Toda-Yamamoto approach

VAR Granger causality/block exogeneity Wald tests			
Null hypothesis	X^2	-value	Granger causality
UR does not cause GE	6.184	0.045	Unidirectional
GE does not cause UR	1.517	0.468	$GE \xrightarrow{U} R$
GDPPK does not cause GE	3.553	0.169	
GE does not cause GDPPK	0.93	0.628	
EQ does not cause GE	10.634	0.005	Bidirectional
GE does not cause EQ	6.056	0.048	$GE \leftrightarrow EQ$
AG does not cause GE	15.77	0.0004	Bidirectional
GE does not cause AG	21.67	0.0000	$GE \leftrightarrow AG$

Note: The critical values are according to Elliot & Harackiewicz (1996) and **, *** denotes 5% and 1% levels of significance

The results show that the unemployment rate causes green energy. On the other hand, green energy does not Granger-cause the unemployment rate. Unidirectional causality running from unemployment rate without feedback from green energy, therefore, exists. The relationship between green energy and per capita income (GDPPK) shows neutral causality, which implies that no evidence of causality from either the green energy variable or gross domestic product per capita exists.

The relationship between green energy policy and educational quality exhibits a bidirectional causality running from green energy to educational quality and feedback from educational quality to green energy policy variables. The relationship between green energy and agricultural development also exhibits bi-directionality. It is, therefore, assumed that causality running from green energy to agricultural development exists, with feedback running from agricultural development to the green energy policy variables. It is necessary to confirm the stability of the approach, to ensure that there is no instability in the models.

4.4 Stability tests

In the test for stability of the Toda-Yamamoto (TY) approach, the serial correlation LM test and the unit circle test were employed to evaluate the stability of the TY approach to Granger-causality.

4.5 Serial correlation Lagrange multiplier (LM) tests

Table 6 tabulates the results of the serial correlation LM test conducted on the lag selection for the TY Granger-causality approach.

Table 6. Serial correlation LM test

VAR residual serial correlation LM test		
Lags	LM-stat	Probability
1	45.166	0.008
2	22.462	0.609
3	38.29	0.043
4	27.7	0.322
5	25.968	0.409
6	19.613	0.767
7	19.828	0.756
8	31.523	0.172

Source: Researchers' analysis

The first column of Table 6 shows the number of lags. The second represents the Lagrange multiplier statistics and the third, is probability. The null hypothesis of 'no serial correlation' is rejected from the first lag. The second lag was the choice of lag for this research because it is the lag with the best stability of the model. The probability of the lag is also higher than the 5% level of significance. The study, therefore, accepts the hypothesis of no serial correlation on the second lag. The stability of the model was also analysed using a unit circle test.

4.5.1 The Unit Circle Test

The unit circle test illustrated in Figure 3 was applied to investigate the stability of the Toda-Yamamoto model. The zeros fall within the unit circle, which indicates the relationship between green energy and the environmental model, although two of the zeros are on the circle but not beyond the 1.0 grid line. Evidence of co-integration among the variables and slight stability, therefore, exists.

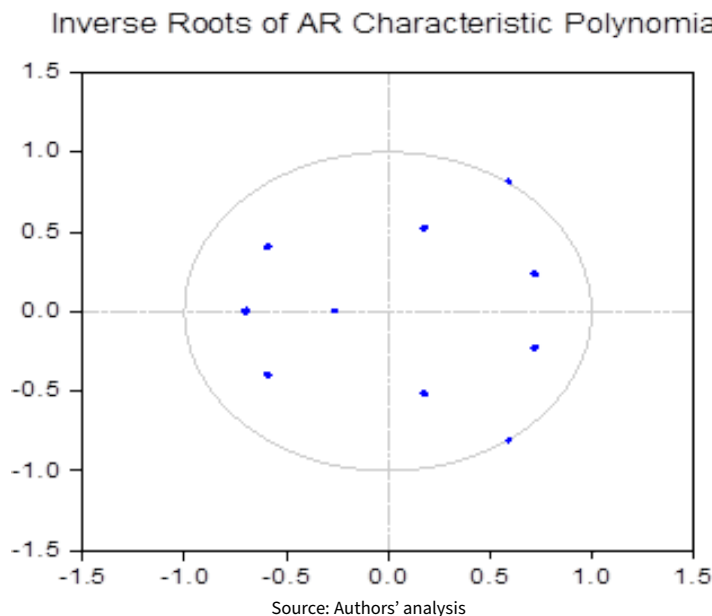


Figure 3. The unit circle test

5. Conclusion

This study investigated the impact of green energy policies on achieving sustainable standards of living or social sustainability in South Africa. The autoregressive distributed lag (ARDL) bounds test was applied to estimate the long-term relationship between green energy and educational quality, agricultural development, unemployment rate and per capita income in South Africa from 1994 to 2016. The Toda Yamamoto approach was also adopted to determine the direction of causality between the variables.

The result reveals a significant and positive inter-relationship between green energy unemployment rate, and educational quality. The results showed that policies to provide welfare supports to the unemployed to afford green energy that can assist in diverting to entrepreneurial activities should be activated, and also ensure the growth of quality education should be part of the reasons to increase the consumption of green energy in South Africa within the review period. The study found a positive and significant impact of agricultural development on green energy consumption, which implies that agricultural development increased green energy in South Africa. This finding indicates that agricultural development will cause an increase in the consumption of green energy. To achieve sustainable agriculture or green agriculture in the country, the government should, therefore, implement policies that can achieve adequate consumption of green energy.

The negative and insignificant relationship between green energy consumption and gross domestic product per capita is an indication that living standards have not yet improved to such an extent that it has a significant impact on the higher consumption of green energy in South Africa. It suggests that programmes and policies to improve the standards of living by supplying more electricity to households should be oriented towards green energy adoption in South Africa.

To achieve sustainable standards of living, the present study, therefore, recommends that the government should direct various energy policies to the needs of the poor and disadvantaged groups. This will assist in attaining social sustainability in such areas by creating jobs from entrepreneurial opportunities, and ultimately alleviating poverty. This type of strategy includes making available patented green energy innovations to poorer households. There is a need to improve the greening

of agriculture. The greening of agriculture is an innovative way of ensuring food security for all (Sustainable Development Goals 1 and 2), reducing natural resource depletion, and soil degradation, reducing soil nutrient loss, and reducing erosion and pollution. Greening agriculture will, therefore, assist in achieving a sustainable economy and an environment with an indirect positive effect on sustainable higher standards of living. There are four basic ways through which innovations can contribute to the greening of agriculture, namely the development of new science and generic technologies with the potential for green energy; national integrated green regimes; farming system innovations; and ensuring policy-driven mechanisms to encourage a green agenda (Hall & Dorai, 2010). The present study has, therefore, confirmed that green energy policies may have an ameliorative influence on lifting the living standards of South African citizens.

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Conflict of interest

The authors declare that they submit this manuscript to the journal without any known conflicts of interest.

Ethical approval

This research complies with ethical standards concerning this manuscript. We declare that all ethical practices have been followed concerning the development, writing and publication of this article. We also obtained an ethics clearance certificate from our institution for this study.

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