THE DYNAMICS OF ECONOMIC GROWTH IN SOUTH AFRICA: DOES RENEWABLE ENERGY CONSUMPTION MATTER?

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Abstract: In this paper, the impact of renewable energy consumption on economic growth in South Africa has been examined during the period from 1990 to 2019. The study aims to establish whether or not renewable energy consumption matters in the economic growth process of South Africa. Empirical evidence to date on the renewable energy consumption and economic growth nexus is not only scanty but also inconclusive, calling for a study of this nature. Using the ARDL-bounds testing approach, the study failed to find any significant impact of renewable energy consumption on economic growth in South Africa, irrespective of whether the regression analysis is conducted in the short run or in the long run. The findings of this study, therefore, lend more support to the neutrality hypothesis, where renewable energy consumption has no significant impact on economic growth. Based on these empirical results, we can conclude that energy conservation can be pursued in South Africa without jeopardizing the economic growth efforts of the country.

Keywords: South Africa, renewable energy consumption, energy mix, economic growth

1. INTRODUCTION

The importance of renewable energy in the energy mix has been increasingly acknowledged at a global level. The advantages of renewable energy in an effort to enhance global energy security and the environment are irrefutable and have been widely discussed. However, its impact on economic growth remains under-examined; and where efforts have been made to explore the nexus, the outcome remains inconclusive. A study on the impact of renewable energy consumption on economic growth, therefore, cannot be overemphasized.

Even at the national level, South Africa is a party to the United Nations Framework Convention on Climate Change (UNFCCC) and a signatory to various the Conference of the Parties (COP), including the famous COP 17, displaying high commitment levels to lowering gas emissions and increasing renewable energy production and consumption (Department of Energy, 2011; United Nations, 2022). With such levels of commitment by South Africa, it can only be prudent to have the renewable energy consumption and economic growth nexus put under empirical test.

In addition to conflicting evidence on the subject, the study was motivated by the growing emphasis on the importance of renewable energy in the total energy mix in South Africa, on the one hand, and the dire need for renewed effort towards propelling economic growth as South Africa, on the other (Xesibe and Nyasha, 2020). One empirical question remains: Do these efforts have any contribution to economic growth and neutralisation of the triple threat facing South Africa? The answer to this question has key policy implications.

The nexus between renewable energy consumption and economic growth nexus is still at a nascent stage, with evidence inclined mainly towards the positive impact of renewable energy on economic growth (see, among others, Cetin, 2016; Haseeb *et al*., 2019; Kamoun *et al*., 2019; Majeed *et al*., 2021). However, empirical evidence to the contrary has also been found (see Tsaurai and Ngcobo, 2020; Venkatraja, 2020, among others), as well as that attesting to no impact between the two (see Nyoni and Phiri, 2018; Smolovic *et al*., 2020, in traditional member states). Although such empirical evidence is thinner than that confirming the positive impact of renewable energy on economic growth, its mere existence, attesting otherwise, points to the inconclusivity of empirical evidence and is a strong signal that the impact of renewable energy consumption on economic growth is not uniform across economies. Hence, the renewable energy and economic growth nexus in South Africa should be put to empirical test, with outcomes aimed at equipping policy makers in the energy and economic growth policy spheres.

In addition, out of the limited number of empirical studies carried out on the relationship between renewable energy consumption and economic growth, a sizable number is on the causality between the two variables (see, among others, Apergis and Payne, 2010; Armeanu *et al*., 2017; Marques and Fuinhas, 2012; Ozcan and Ozturk; 2019), leaving little and conflicting evidence of the impact of the renewable energy consumption on economic growth (see Majeed *et al*., 2021; Venkatraja, 2020; Smolovic *et al*., 2020).

A further review of the empirical literature on the renewable energy-growth nexus evidence reveals that most studies on the subject have been on Europe, Asia, and America, leaving Africa with little to cling to as evidence (see Alper and Oguz, 2016; Anwar *et al*. 2017; Apergis and Payne, 2010).

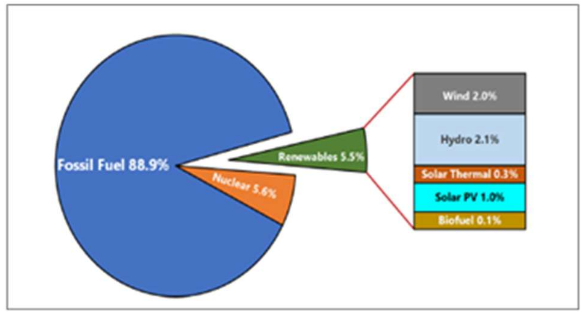
Moreover, within those limited studies, most of them utilised group-based analysis methodologies, where countries are grouped, even though it is now well-known that country-specific effects could be lost with such methods.

Against this background, in this study, the impact of renewable energy consumption on economic growth in South Africa is empirically examined from 1990 to 2019 using the ARDL bounds testing approach. The study aims to unravel whether or not renewable energy consumption matters in the economic growth process of South Africa.

The rest of this paper is organised as follows: Section 2 gives an overview of the energy sector and the dynamics of renewable energy in South Africa. Section 3 reviews literature on the impact of renewable energy consumption on economic growth. While Section 4 covers the methodology of the study, Section 5 presents the results and their analysis. Finally, section 6 provides the conclusion and the policy implications of the study.

2. THE DYNAMICS OF RENEWABLE ENERGY AND ECONOMIC GROWTH IN SOUTH AFRICA

South Africa's renewable energy journey began in earnest in 2003, with a White Paper of 2003 on Renewable Energy, which is one of the policy documents that laid the foundation for the promotion of renewable energy technologies such as solar, hydro, biomass, and wind (Department of Mineral Resources and Energy, 2022). This policy document sets a target of how renewable energy technologies could diversify the country's energy mix and secure cleaner energy. In line with the national commitment to transition to a low carbon economy, the Integrated Resource Plan was drawn and promulgated in 201, setting a more ambitious target of 17 800 MW of renewable energy to be achieved by 2030 in respect of the electricity generation mix. Post-2010, efforts were made to increase renewable energy production by introducing the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), which is one of the South African government's urgent interventions to enhance the country's power generation capacity. According to the Department of Mineral Resources and Energy (2022), the main objective of REIPPPP is to secure private sector investment for the development of new electricity generation capacity, giving effect to the policy decision to diversify South Africa's energy mix. Figure 1 displays a visual impression of South Africa's energy mix.

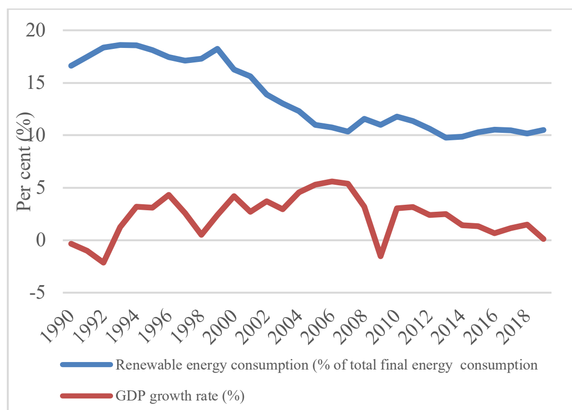


Source: Extracted from Akinbami *et al*. (2021); Data (International Energy Agency "IEA", 2020)

Fig. 1. South Africa's energy mix

As depicted in Figure 1, despite the efforts towards catapulting renewable energy generation, to date, renewable energy remains the smallest part of the country's energy mix, at only 5.5%, leaving the bulk of the country's energy to fossil fuel, at close to 90%. Although solar-based renewable energy has been gaining traction of late, hydro-based renewable energy is the most common source of renewable in South Africa.

From the consumption front, renewable energy consumption in South Africa, as a percentage of total final energy consumption, has been trending downwards over the review period, just like the economic growth trend (World Bank, 2022). Figure 2 summarises South Africa's economic and energy trends over the review period.



Source: Author computations; Data (World Bank, 2022a)

Fig. 2. Trends in renewable energy consumption and economic growth in South Africa (1990-2019)

As displayed in Figure 2, renewable energy consumption slid from 18.6% of total energy consumed in 1993, only for the fall to be momentarily broken between 2007 and 2008, with 2013 marking its lowest consumption level of 9.7% (World Bank, 2022). Thereafter, the trend stabilised, even edging up marginally to 10.5% in 2019 (World Bank, 2022), largely driven by the national stance to support renewable energy as efforts to reduce greenhouse gases intensified. According to Nhede (2022), renewable energy production and consumption are expected to take off, driven by national renewable energy targets, coal plant decommissioning, market-driven regulation, electricity regulations on new generation capacity, green hydrogen advancement, and declining costs of renewable energy. Meanwhile, the country has been struggling to achieve a stable economic growth rate, which has been, in the main, trending downwards over the period under review. The economy buoyed only in the late 1990s and the mid-2000s when the growth rate was as firm as 5.6% in 2006. While renewable energy consumption as a percentage of total final energy consumption averaged 13.6% per annum for the entire review period, economic growth averaged 2.2% over the same period (World Bank, 2022).

3. LITERATURE REVIEW

Although the nexus between renewable energy consumption and economic growth is still at a nascent stage, there exists empirical evidence on the subject. However, this empirical evidence has been conflicting and hence, inconclusive. A review of such literature has given rise to three distinct groups.

The first group is for studies that have found a positive relationship between the two variables, where renewable energy consumption has a positive impact on economic growth. Such studies concluded that energy consumption matters in a positive way in the economic growth process of an economy. Empirical studies in support of this strand include Apergis and Payne (2010) for OECD economies; Cetin (2016) in seven emerging countries; Charfeddine and Kahia (2019) for the Middle East and North Africa region; Haseeb *et al*. (2019) for Malaysia over the 1980-2016 period; Kamoun *et al*. (2019) for a panel of 13 OECD countries; Khobai and Le Roux (2017) for South Africa; Mahjabeen *et al* (2020) in the case of D-8 countries; Majeed *et al*. (2021) in the case of 174 developed and developing countries, during the period from 1980 to 2019, using the fixed effects, random effects, and two-step system GMM estimation approaches; Marinaș *et al*. (2018) in the selected Central and East European economies using the error correction model; Rafindadi and Ozturk (2017) for Germany; Smolovic *et al*. (2020) but only in the long run in both the traditional and new European Union (EU) member states, over the period from 2004 to 2018 in a dynamic panel ARDL setting; and Zrelli (2017) in the case of the Mediterranean countries.

The second strand houses the empirical literature that acknowledges the existence of a significant relationship between renewable energy consumption and economic growth but further qualifies that the impact of the former on the latter is negative. These empirical studies include those by Ocal and Aslan (2013) for Turkey over the period 1980-2010 period; Smolovic *et al*. (2020) but only in new member states in their study in both the traditional and new European Union (EU) member states; Tsaurai and Ngcobo (2020) for BRICS economies because of lack of access to education; and Venkatraja (2020) for BRICS economies over during the period from 1990 to 2015. The authors attribute this negative effect to varied reasons, ranging from higher initial investment required for renewable energy deployment and the high transition cost from conventional energy sources to renewables to lack of access to education, claiming that increasing expenditure and ensuring access to education can help to ensure favourable economic effects of renewable energy use.

Then there is the third strand which stresses that renewable energy consumption does not matter in the economic growth process, as the two variables are not correlated. Though unpopular, this strand has been gaining traction of late, as noted by the increasing amount of empirical evidence in its support. Researchers that have argued that the linkage between renewable energy consumption and economic growth could be, at best, described as neutral include Dogan (2016) using Turkish regional data; Nyoni and Phiri (2018) in the case of South Africa; Ocal and Aslan (2013) in the case of Turkey; and Smolovic *et al*. (2020) - but only in traditional member states, in their study in both the traditional and new European Union (EU) member states.

Although there is little consensus on whether renewable energy consumption matters for economic growth or not, globally, the scale tilts towards the empirical literature attesting to the positive impact that renewable energy consumption has on economic growth.

4. METHODOLOGY

ARDL Bounds Testing Procedure

The autoregressive distributed lag (ARDL)-bounds testing approach is used in this study to empirically investigate the impact of renewable energy consumption on economic growth in South Africa. The chosen methodology has numerous advantages, with the top three being superior small sample properties, automatically addressing the endogeneity issues, and it does not impose the restrictive condition that all the variables must be integrated of the same order (Nyasha *et al*, 2022; Nyasha and Odhiambo, 2016; 2020; Pesaran *et al*., 2001)). In recent times, this approach has also been increasingly used in empirical research – attesting to its superiority over conventional methods.

Empirical Model Specification

To fully specify the model and address the omission-of-variable bias, four other variables known in the literature to be linked with economic growth are added. These are trade openness, domestic investment, human capital, and inflation (see Nyasha and Odhiambo, 2019). According to the growth theory, the first three additional variables exert a positive impact on economic growth; hence, their coefficients are expected to be negative, while the last additional variable exerts a negative impact on economic growth, and its coefficient is expected to be negative. The empirical model employed in this study to examine the impact of renewable energy consumption on economic growth is expressed in the ARDL format as follows:

$$\Delta GDP_t = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \gamma_{2i} \Delta REC_{t-i} + \sum_{i=0}^{n} \gamma_{3i} \Delta TOP_{t-i} + \sum_{i=0}^{n} \gamma_{4i} \Delta DIN_{t-i} + \sum_{i=0}^{n} \gamma_{5i} \Delta POP_{t-i} + \sum_{i=0}^{n} \gamma_{6i} \Delta INF_{t-i} + \gamma_7 GDP_{t-1} + \gamma_8 REC_{t-1} + \gamma_9 TOP_{t-1} + \gamma_{10} DIN_{t-1} + \gamma_{11} POP_{t-1} + \gamma_{12} INF_{t-1} + \mu_t \dots\dots\dots (1)$$

Where:
GDP = Economic growth= real GDP growth rate
REC = Renewable Energy Consumption (% of total energy consumed)
TOP = trade openness = sum of imports and exports (% of GDP)
DIN = Domestic investment = gross fixed capital formation (% of GDP)
POP = Human capital = population growth (annual %)
INF = Inflation, consumer prices (annual %)

γ_0 is a constant, γ_1- γ_6 and γ_7- γ_{12} are short-run and long-run coefficients, Δ is the difference operator, n is the lag length, and μ_t is the white noise-error term.

The ARDL-based error-correction model, based on the ARDL model specified in equations (1), is specified as follows:

$$\Delta GDP_t = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \gamma_{2i} \Delta REC_{t-i} + \sum_{i=0}^{n} \gamma_{3i} \Delta TOP_{t-i} + \sum_{i=0}^{n} \gamma_{4i} \Delta DIN_{t-i} + \sum_{i=0}^{n} \gamma_{5i} \Delta POP_{t-i} + \sum_{i=0}^{n} \gamma_{6i} \Delta INF_{t-i} + \gamma_{13} ECM_{t-1} + \mu_t \dots\dots\dots (2)$$

Where:
ECM = Error-correction term;
γ_{13} = coefficients for the error-correction term;
μ_t = mutually uncorrelated white-noise residuals; and all other variables and characters are as described in equations 1.

Data Sources and Definition of Variables

The annual time series data, covering the period from 1990 to 2019, utilised in this study were sourced from the World Bank Economic Indicators (World Bank, 2022).

5. EMPIRICAL RESULTS

Unit Root Tests

Although the ARDL bounds testing approach does not require all variables to be I(1) before cointegration tests are done, in this study, unit root tests were carried out to ensure that no variable is integrated of order two or higher, as this would invalidate the results. Dickey-Fuller generalised least squares (DF-GLS) and Phillips-Perron (PP) tests were employed for the unit root test, and the stationarity tests' results for all the study variables are summarised in Table 1.

Table 1: Stationarity Tests of all Variables

Dickey-Fuller generalised least square (DF_GLS)					**Phillips – Perron (PP)**			
	Variables in levels		Variables in 1st difference		Variables in levels		Variables in 1st difference	
Variable	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend
GDP	-2.397**	-2.624	-	-6.024***	-2.611	-2.237	-6.356***	-8.866***
REC	-0.311	-1.527	-2.122**	-4.230***	-0.631	-1.955	-4.388***	-4.257**
TOP	-1.407	-2.885	-5.717***	-6.149***	-1.400	-2.775	-9.018***	-11.999***
DIN	-2.134**	-2.419	-	-3.450**	-2.201	-2.461	-3.476**	-3.581**
POP	-0.197	-2.502	-1.663*	-2.891*	-1.729	-1.254	-2.627*	-3.235*
INF	-1.337	-2.605	-4.604***	-5.302***	-2.109	-2.392	-5.415***	-8.456***

Notes: *, ** and *** denotes stationarity at 10%, 5% and 1% significant levels respectively; S = Stationary; N = Non-stationary.

As shown in Table 1, the unit root test results confirmed that all the variables in the study are either stationary in levels or in first difference – thereby confirming the suitability of the chosen estimation techniques for the study.

Bounds Test for Cointegration

Following the confirmation that all variables are integrated of order one or lower, the study proceeded to examine the existence of a long-run equilibrium relationship among the variables in the study's specified model. To this end, the ARDL bounds testing procedure is utilised in a two-stepwise fashion. Firstly, the order of lags for the first differenced variables in equation (1) is determined from the unrestricted model. This this followed by the application of the bounds F-test in order to establish whether there is a long-run relationship among the variables in the specified model. Table 2 reports the cointegration results.

Table 2: Bounds F-test for Cointegration

Dependent Variable	**Function**		**F-statistic**	**Cointegration Status**		
GDP	F(GDP|REC, TOP, DIN, POP, INF)		4.938***	Cointegrated		
Asymptotic Critical Values						
Pesaran *et al*. (2001), p.300, Table CI(iii) Case III	1%		5%		10%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	3.41	4.68	2.62	3.79	2.26	3.35

Note: *** denotes statistical significance at 1% level

The results of the ARDL bounds test for cointegration displayed in Table 2 reveal that the calculated F-statistic (4.938) is higher than the upper-bound critical value reported by Pesaran *et al*. (2001) in Table CI(iii) Case III, at 1% significance level (4.68). These results, therefore, confirm that the variables in the specified model are cointegrated.

Estimated ARDL Model

Once cointegration is confirmed among the variables in the study, the study proceeded with the estimation of long-run and short-run coefficients. The optimal lag length for the model is determined using the Akaike Information Criterion (AIC), and the optimal lag length selected is ARDL(1,1,1,0,2,0). The SIC-based model was preferred because it was more parsimonious than the AIC-based model. The results of the coefficient estimations are summarised in Table 3. The long-run results are reported in Panel A, while the short-run results are reported in Panel B.

Table 3: Empirical Results of the Estimated ARDL Model

Panel A: Estimated long-run coefficients [Dependent variable: real GDP growth rate (GDP)]	
Regressor	Co-efficient (t-statistic)
C	16.426 (1.571)
REC	0.098 (0.355)
TOP	-0.274* (-1.991)
DIN	0.612** (2.116)
POP	0.186** (2.472)
INF	-0.196* (-1.771)
Panel B: Error-correction representation of the selected ARDL model [Dependent variable: real GDP growth rate (ΔGDP)]	
ΔREC	-0.600 (-1.336)
ΔTOP	0.055 (0.602)
ΔDIN	0.546* (1.822)
ΔPOP	0.143* (1.992)
ΔPOP1	0.624* (2.029)
ΔINF	-0.175* (-1.931)
Ecm (-1)	-0.893*** (-4.274)
R-Squared 0.787 R-Bar-Squared 0.661 SE of Regression 1.072 F-Stat F(7,20) 8.952[0.000] Residual Sum of Squares 9.546 DW statistic 2.221	

Note: ** and *** denote stationarity at 5% and 1% significance levels respectively.
ΔPOP1= POP(-1)-POP(-2)

The results reported in Table 3 show that, contrary to expectations, renewable energy consumption has no impact on economic growth in South Africa. These results apply irrespective of whether estimation is done in the long run or in the short run; and have been confirmed by the long- and short-run coefficient of renewable energy consumption (REC and ΔREC), respectively, that have been confirmed to be statistically insignificant. Although contrary to expectations, the results are not unusual (see Nyoni and Phiri, 2018; Ocal and Aslan, 2013; Smolovic *et al*., 2020, in traditional member states). There could be a number of explanations behind these unpopular and unexpected results. The magnitude of the role played by renewable energy adoption in curbing negative environmental implications largely depends on both the type of renewable energy deployed and the total share of renewable energy in the energy mix. In the case of many African countries that are beginning to adopt renewable energy but are still heavily reliant on fossil fuels, such as South Africa, the environmental implications caused by carbon emissions could still be compounding (Lee, 2019). Additionally, the neutrality hypothesis is supported in economies with nascent renewable energy sectors with less market penetration (Smolovic 2020). Gross inefficiencies could also be in the way, as the industry is young. These arguments, in one way or the other, cement the argument that it could be possible that there is a minimum threshold above which renewable energy consumption has a positive impact on economic growth and below which it may have a neutral effect on economic growth, as the case with South Africa, in this study.

Other results of the study show that the coefficient of investment and population is positive and statistically significant, as expected, suggesting that investment and human capital positively impact on economic growth. These results apply both in the long and short run. Human capital in the previous period has also been found to have a positive impact on economic growth in the short run. Meanwhile, trade openness was found to exert a positive impact on economic growth in South Africa, however, only on the long run. Consistent with expectations, the coefficient of inflation came out negative and statistically significant, both in the long and short run – confirming that in South Africa, inflation is bad for economic growth. The coefficient of ECM (-1) is also found to be negative and statistically significant, as expected, confirming the cointegration results found earlier in the study.

To check for model robustness and stability, diagnostic tests were performed, and the results are summarised in Table 4.

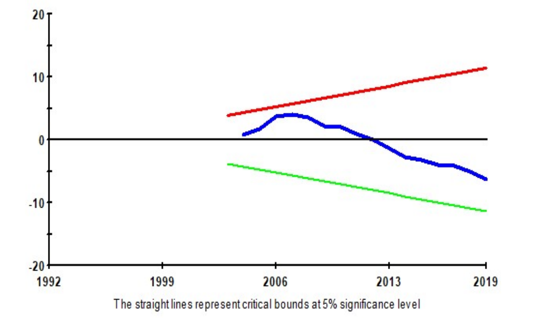
Table 4: Diagnostic Tests

LM Test Statistic	Results
Serial Correlation: CHSQ(1	0.048[0.770]
Functional Form: CHSQ(1)	0.053[0.842]
Normality: CHSQ (2)	2.824[0.244]
Heteroscedasticity: CHSQ (1)	0.300[0.584]

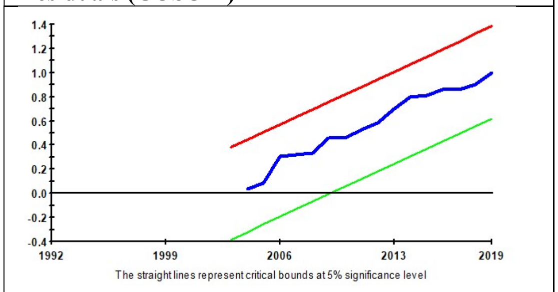
As shown in Table 4, the results confirm that the model passed tests against serial correlation, heteroscedasticity, normality, and functional form, implying that the results of the study can be relied upon. Similarly, the stability tests based on the Cumulative Sum of Recursive Residuals and Cumulative Sum of Squares of Recursive Residuals reported in Table 5 also show that the parameters in this model are stable over the sample period.

Table 5: Plot of CUSUM and CUSUMQ

Plot of Cumulative Sum of Recursive Residuals (CUSUM)



Plot of Cumulative Sum of Squares of Recursive Residuals (CUSUM)



CONCLUSION

In this paper, the impact of renewable energy consumption on economic growth in South Africa has been examined during the period from 1990 to 2019. The study aims to establish whether or not renewable energy consumption matters in the economic growth process of South Africa. The study was motivated by the growing emphasis on the importance of renewable energy in the total energy mix, on the one hand, and the dire need for a renewed effort towards propelling economic growth in South Africa, on the other. To top it all, empirical evidence, to date, on the impact of renewable energy consumption on economic growth is not only scanty but also inconclusive, calling for a study of this nature.

Using the ARDL-bounds testing approach, the study failed to find any significant impact of renewable energy consumption on economic growth in South Africa, irrespective of whether the regression analysis is conducted in the short run or in the long run. The findings of this study, therefore, lend more support to the neutrality hypothesis, where renewable energy consumption has no significant impact on economic growth. Based on these results, renewable energy consumption may not be directly linked to increased economic growth; and policy makers in South Africa are recommended to craft and implement pro-economic growth policies independently from renewable energy-related policies, should they wish to foster economic growth. Energy conservation can be pursued without jeopardizing the economic growth efforts of the country. This study highlights the importance of a strong institutional framework in ensuring that renewable energy utilization is in alignment with the environmental sustainability targets; and that sufficient policy efforts are made to ensure a desired national energy mix is achieved in South Africa such that the economy may harness the economic benefits of renewable energy.

Further studies are recommended to explore the disaggregated renewable energy impact on economic growth in South Africa, for various types of renewable energy may have a different impact on economic growth. For instance, according to Qudrat-Ullah and Nevo (2021), biomass energy is renewable, but its excessive consumption may sometimes lead to massive environmental pollution, which takes a negative toll on the economy, ultimately. It will be interesting to note how different the results of these future studies will be from the ones revealed by this study.

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