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Article

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Is there a non-linear relationship between renewable energy consumption and economic growth in Namibia?

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ABSTRACT

This paper examines whether renewable energy has an asymmetric or symmetric impact on economic growth in Namibia for the period 1990 to 2020. The study was motivated by the growing importance of renewable energy in the economic growth process of many economies. Further, knowing whether this relationship is linear or not is crucial for policy formulation purposes, yet no such information is known for Namibia. The study used the Wald test to examine the asymmetric relationship between renewable energy and economic growth. The Wald test results revealed that the relationship between renewable energy and economic growth in Namibia is symmetric, both in the short and long run. Hence, the study only estimated the linear ARDL model. The findings indicate that renewable energy has a positive and significant impact on economic growth in the long and short run. Therefore, the study recommends that Namibia's government should continue to pursue policies that will enable the government to expand its renewable energy sources as they contribute to economic growth.

IMPACT STATEMENT

This study explores the relationship between renewable energy consumption and economic growth in Namibia, specifically investigating whether this relationship is linear or non-linear. The research is particularly relevant given Namibia's long-term goal of increasing the share of renewable energy in total electricity generation to 60% by 2035. While the study did not identify a non-linear relationship between renewable energy consumption and economic growth, it revealed a consistent positive linear impact of renewable energy consumption on economic growth in both the short and long run.

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SUBJECTS

Macroeconomics;
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Policy

1. Introduction

The relationship between energy and economic growth has gained prominence in recent decades. Energy can be harnessed from various sources, which could be classified as renewable and non-renewable. Unfortunately, for a long time, the traditional growth theories did not incorporate the critical role that energy plays in production alongside other factors of production (see Abosedra et al., 2015; Odhiambo, 2023). The role of energy in the growth process was only given prominence in the new growth models that included energy among other factors of production, such as land, labour, capital, etc (see Abosedra et al., 2015; Odhiambo, 2023). Some recent studies have also argued that the role of energy in economic growth is more pronounced when its supply is scarce and that when it is abundant, its significance diminishes somewhat (see Stern, 2011). In addition, some previous studies have also argued that the link between energy and growth may be non-linear and that positive and negative shocks in energy consumption would impact differently on economic growth (see Odhiambo, 2023).

Although several studies have been conducted to examine the link between energy and economic growth in many African countries, most of the previous studies have mainly delved into the relationship between aggregate energy consumption and economic growth, and little focus has been placed on the

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critical role that renewable energy plays in economic growth and sustainable development (See Majekodunmi et al., 2023; Odhiambo, 2021; Nyasha et al., 2018; Odhiambo, 2009; Narayan & Singh, 2007). Most of the non-renewable sources of energy that have been covered in the previous studies relate mainly to fossil fuels, which include oil, natural gas, and coal.

Indeed, many African countries have not fully explored the dynamic relationship between renewable energy consumption and economic growth. Where such studies have been conducted, the findings have remained inconclusive. Yet, renewable energy sources have been found to be one of the cornerstones of sustainable development since they contribute significantly to environmental and climate protection (See Sharma 2010). Some of the previous studies which have been conducted on the relationship between renewable energy and economic growth in African countries include studies such as those of Nyasha (2024) in the case of Zimbabwe; Nyasha and Odhiambo (2022) in the case of Zambia; Somoye et al. (2022) in the case of Nigeria; Gyimah et al. (2022) in the case of Ghana, among other studies. Unfortunately, most of these studies have focused mainly on the linear relationship between renewable energy and economic growth in the studied countries. Very few studies have explored the link between renewable energy and economic growth in a non-linear setting.

It is against this backdrop that this study aims to examine whether the relationship between renewable energy and economic growth is linear or non-linear using annual time-series data from Namibia. To our knowledge, this may be the first study to examine the existence of a nonlinear relationship between renewable energy and economic growth in Namibia using a non-linear ARDL model.

The rest of the paper is divided into six sections. Section 2 presents an overview of renewable energy exploration and economic growth in Namibia. Section 3 reviews the empirical literature on the relationship between energy consumption and economic growth, while Section 4 deals with the methodology, data, and estimation techniques. Section 5 presents the empirical findings, while Section 6 concludes the study and offers policy implications.

2. Renewable energy exploration and economic growth in Namibia: an overview

Namibia makes an interesting case as its energy sector has been undergoing progressive liberalisation in recent years. The supply of electricity, for example, has over the years been dominated by Namibia Power Corporation (Pty) Ltd., a state-owned enterprise, which has been responsible for not only the generation of electricity, but also the transmission, distribution, and sale of electricity to the end users (GIZ, 2022). Owing to the high demand for electricity vis-à-vis its supply, Namibia has been relying largely on imported electricity to meet its shortfall. In particular, the bulk of the country's electricity imports, which account for about 60% of its total demand, has been largely sourced from South Africa. Other countries with which Namibia has also signed power purchase agreements include Zimbabwe, Zambia, Mozambique, the Democratic Republic of Congo (DRC) and Botswana (International Trade Administration 2024). Unfortunately, the overreliance on imported power from South Africa (Eskom) is currently not sustainable as South Africa also presently needs more electricity owing to the increased demand for electricity from its own economy.

According to Namibia's National Integrated Resource Plan (NIRP) of 2016, the country aims to expand its power plant capacities to reach 1677 MW by 2035 in order to reduce its electricity imports. The main sources of local electricity supply in Namibia are hydro, solar IPP and coal, which accounted for 52%, 26% and 18%, respectively, in 2019. Other local electricity sources are fuel oils and wind, which accounted for 3% and 1% of the supply, respectively, during the same period (WWF, 2023).

To address its increasing energy demands and to promote sustainable development, Namibia has invested heavily in non-renewable energy sources. For example, the country plans to expand its renewables to account for about 60% of electricity generation in 2035. The main sources of renewable energy are photovoltaics (PV), wind power, biomass and concentrated solar power (CSP), whose total planned capacities are 229.5 MW, 149 MW, 80 MW, and 250 MW, respectively. By 2030, the country aims to install about 510 MW of renewable energy capacity, which will be connected to the grid (GIZ, 2022).

Owing to the high cost of connecting remote rural households to the electrical grid, the country decided to launch its Off-grid Energisation Master Plan (OGEMP), which is aimed at promoting the use of renewable energy for communities that are not connected to the national grid (ITA, 2024).

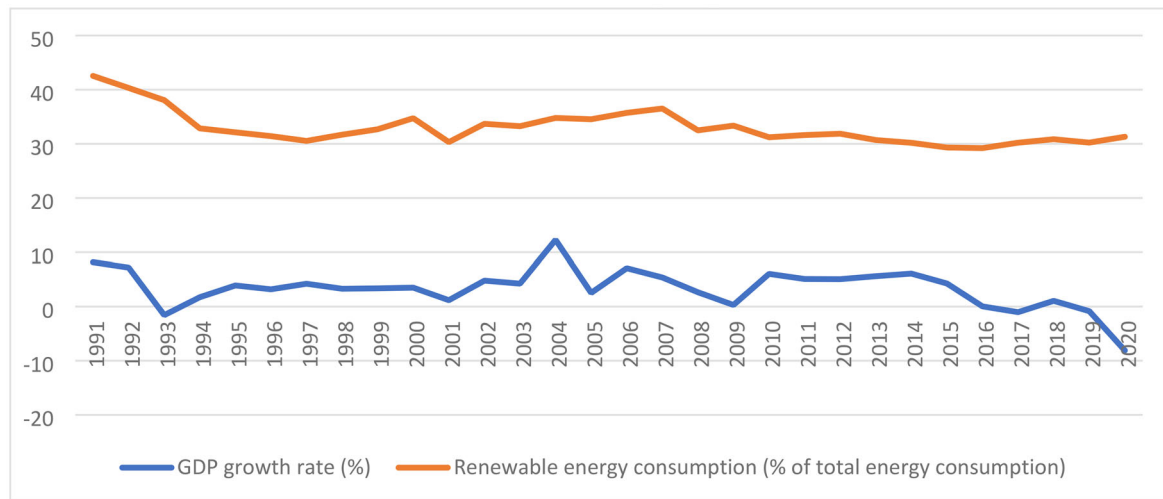


Figure 1. Trends of renewable energy consumption and economic growth in Namibia (1991–2020).

Source: World Bank. (2021b).

On the economic growth front, Namibia's economic growth trajectory remains solid and strong when compared with that of many other African countries. As of 2022, the country was ranked number eight in terms of GDP per capita, which was estimated to be US\$4810 (see <https://www.statista.com/statistics>). Despite the COVID-19-related challenges that affected the economies of many countries negatively, the Namibian economy managed to recover swiftly from the pandemic, following the lifting of the COVID-19 restrictions and continued recovery in both secondary and primary activities. This led to a significant growth in real GDP growth from 3.5% in 2021 to 4.6% in 2022 (See African Development Bank, 2023). This impressive economic growth has been driven largely by private capital investments in mining and public investments in infrastructure (World Bank, 2021a). The country's economic growth has been supported by, among others, structural transformation and urbanisation (World Bank, 2021a). The discovery of new minerals, as well as the continued investment in green energy, has also contributed significantly towards increased growth, employment, and diversification. The country has also benefitted immensely from its good governance, which has enabled it to attract foreign direct investment, especially in the extractive industry (see World Bank, 2021a). Figure 1 shows the trends of renewable energy consumption and economic growth in Namibia during the period between 1991 and 2020.

3. Literature review

The empirical literature on whether the relationship between renewable energy use and economic growth is linear or non-linear is still scant. Traditionally, most studies that investigated the impact of renewable energy on economic growth have treated the relation as linear (see Nyasha, 2024; Hlongwane & Daw, 2023; Nyasha & Odhiambo, 2022; Kamoun et al., 2019; Haseeb et al., 2019; and Cetin, 2016, among others).

In recent times, growing focus has been placed on understanding whether the renewable energy use and economic growth nexus is linear or nonlinear. So far, the outcome is not yet conclusive. Ferhi and Kamel (2024) found the relationship between renewable energy consumption and economic growth to be nonlinear in their study of 24 OECD countries, using 1990–2015 data and panel-based methodologies, so did Chen et al. (2020) using a 103-country sample in the 1995 to 2015 period; and Tiba (2019) for 90 economies, subdivided into three sub-panels (low-, middle-, and high-income) during the 1990–2015 period. Shahbaz et al. (2020) also confirm the existence of a non-linear relationship; however, only in the long run for France, Japan, Italy, and the UK, in their G-7 countries study using a Nonlinear Auto-Regressive Distributed Lag model (NARDL) during the period from 1995Q1–2015Q4. However, in the same mood, the same study revealed that for Germany, Canada and the US, the nature of the relationship could not be established as no long-run equilibrium between renewable energy consumption and economic growth was found for these countries. Their results lent support to Nyoni and Phiri (2018),

whose results failed to confirm any linear or nonlinear cointegration effects of renewable energy consumption on South African economic growth.

Coming back to the linear relationship, the literature on the impact of renewable energy on economic growth, though scarce, is increasingly getting traction and has been on the rise in recent times. Despite its gradual increase, the results have been far from being conclusive. While some studies have attested to the positive impact of renewable energy use on economic growth, others concluded that the relationship is negative, with some in support of the neutrality hypothesis.

Empirical studies that found renewable energy use to have a positive impact on economic growth are spread across continents, with high a concentration on European countries (see, among others, Smolovic et al., 2020; Marinaş et al., 2018; Rafindadi & Ozturk, 2017). While Smolovic et al. (2020) looked at both traditional and new European Union member states, Marinaş et al. (2018) focused on the Central and East European economies, leaving Rafindadi and Ozturk (2017) to provide coverage for Germany. Despite the differences in methodology – ranging from dynamic panel ARDL to error correction model – the outcome was uniform, attesting to the significant positive impact of renewable energy consumption on economic growth. Although the other two studies found this relationship to hold in the study countries in general, for Smolovic et al. (2020), this relationship was found to hold only in the long run in both the traditional and new European Union member states.

In the Middle East and North African region, Charfeddine and Kahia (2019) and Haseeb et al. (2019) found the relationship of interest to be positive despite differences in specific study countries, methodology and study period. While Charfeddine and Kahia (2019) focused on the 24 countries of the Middle East and North African region during the period from 1980 to 2015, based on the panel vector autoregressive model, Haseeb et al. (2019) study was on Malaysia from 1980 to 2016 using modern econometric techniques. Close to the study, and still in the African continent, is Khobai and Le Roux (2017), who put the impact of renewable energy on economic growth to the test in South Africa and found it to be positive.

Despite the effort put into grouping the relevant empirical studies by continent in which the studies were undertaken, there remained significant literature that could not be associated with one content as it cut across a number of continents (see, among others, Majeed et al., 2021; Kamoun et al., 2019; Zrelli, 2017; Inglesi-Lotz, 2016; Apergis & Payne, 2010). While the study by Majeed et al. (2021) was on 174 developed and developing countries during the period from 1980 to 2019, using pane-based techniques, the one by Zrelli (2017) featured the Mediterranean countries. In the same vein, Kamoun et al. (2019), Inglesi-Lotz (2016) and Apergis and Payne (2010) carried out similar studies for OECD economies using panel-based methodologies and came to the same conclusion.

From the emerging economies front, there is Cetin (2016) who found renewable energy intake to have a positive impact on economic growth in seven emerging countries based on data from 1992 to 2012 and on heterogeneous panel data analysis. Meanwhile, the developing countries coverage was by Mahjabeen et al. (2020), in the case of eight developing countries, using 1990–2016 data and the Cobb Douglas production function within the ARDL, Fully Modified Ordinary Least Square, and Dynamic Ordinary Least Square models and tests. The outcome was the same, attesting to the positive impact renewable energy has on economic growth.

Despite the presence of significant empirical literature pointing to the positive impact of renewable energy on economic growth, further review of empirical literature has revealed that although just a handful, there is also empirical literature to the contrary, supporting the possibility that renewable energy consumption could be detrimental to economic growth. From Europe, the results have found support from Smolovic et al. (2020) only in new EU member states and Ocal and Aslan (2013) in the case of Turkey, while the African support came from Hlongwane and Daw (2023), in their study that focused on South Africa and Zimbabwe, covering the 1990–2019 period.

A similar conclusion was reached by some studies that were cross-cutting continent-wise. For example, Tsaurai and Ngcobo (2020) for Brazil, Russia, India, China, and South Africa (BRICS economies); Venkatraja (2020) for Brazil, Russia, India, and China (BRIC economies); Matei (2018), in the case of 34 OECD economies; and Bozkurt and Destek (2015), but only for Italy and Turkey, among the selected OECD economies in the study. Some of these studies attribute this negative effect to diverse reasons, ranging from higher initial investment required for renewable energy deployment and the high transition cost from conventional energy sources to renewables. Others blame the lack of access to education, claiming that increasing expenditure on, and ensuring access to, education can assist in ensuring desirable effects of renewable energy use on the real economy.

The possibility of renewable energy consumption having a neutral or insignificant effect on economic growth could not be dismissed. Though unpopular, evidence of this effect has been gradually mounting, as noted by the increasing number of empirical studies in its support. To date, such evidence has only been in Europe [see Dogan (2016) using Turkish regional data and Smolovic et al. (2020) in some traditional member states]; and Africa [see Nyoni and Phiri (2018) in the case of South Africa].

From the reviewed empirical literature, it can be concluded that: although the renewable energy-growth nexus is still nascent, it has been gaining traction of late and is increasingly becoming a subject of interest to economists, policy makers and politicians alike; despite the non-conclusively of the relevant literature reviewed, the conventional wisdom is in support of the renewable energy having a positive impact on economic growth; notwithstanding the conventional wisdom established, the presence of empirical support to the negative and neutral impact of renewable energy use on economic growth warrants that the statement “renewable energy consumption is good for economic growth” be taken with a pinch of salt; most of the reviewed empirical literature is on non-African regions, depriving Africa in general, and Namibia, in particular, the needed specific empirical evidence required for research-based policy making; and given the need to stimulate the Namibian economy on the one hand, and the inconclusive studies on the renewable energy and economic growth nexus, on the other hand, the need for such a study as this cannot be overemphasized.

4. Estimation techniques and empirical analysis

4.1. Data and Definitions of variables

The annual time series data used is from 1990 to 2020. The data was obtained from the World Bank online database and the measurements are presented in Table 1. The selection of the study period is determined by the availability of data relating to the variables of interest.

4.2. Model specification

The general model used to examine the impact of renewable energy consumption on economic growth can be expressed as follows:

$$Y = f(\text{RE}, \text{INV}, \text{L}, \text{INT}, \text{TO}) \quad (1)$$

Where: Y = Economic growth, RE = Renewable energy, INV = Investment, L = Labour, INT = Interest rate, TO = Trade openness.

The above model is derived from the standard growth model, which includes investment and labour as key variables. To accommodate the current study, we included renewable energy, which is our policy variable, and interest rate and trade openness as control variables.

The dependent variable is economic growth, measured by the annual growth rate in Namibia. In addition to renewable energy, control variables that have an impact on the growth of the economy are included in the study to prevent omitted variable bias in the specification. The selection of the explanatory variables is underpinned by theoretical and empirical literature. Investment measured by gross fixed capital formation has been found in the literature to have a positive impact on economic growth (see Barro (2003), Fetahi-Vehapi et al. (2015), Saungweme et al. (2023). Labour is also one of the determinants of economic growth, and labour is likely to lead to an increase in economic growth. Studies such as Radelet et al. (2001) have found that the growth of the working-age population is positively and significantly associated with economic growth. Also, Chang and Mendy (2012) found that labour employed is positively associated with economic growth.

Table 1. Definitions of variables and data sources.

Variables	Definitions of variables (Measurements)	Expected signs
Economic growth (Y)	GDP growth (annual%)	
Renewable energy (RE)	Renewable energy consumption (% of total final energy consumption)	+
Investment (INV)	Gross fixed capital formation (% of GDP)	+
Labour (L)	Labour force participation rate, total (% of total population ages 15+)	+
Interest rate (INT)	Real interest rate (%)	+/-
Trade openness (TO)	Trade (% of GDP)	+

The inclusion of interest rates was motivated by its role in investment, which is a determinant of economic growth. A study by Próchniak (2011) has found that interest rate has a negative impact on economic growth. Trade openness has been found to contribute positively to the growth of the economy through an increase in trade activities. An increase in trade has been found to affect economic growth. Therefore, we expect the coefficient of trade openness in economic growth to be positive, as found by studies such as Bhaskara-Rao and Hassan (2011), Keho (2017) and Anyanwu (2014).

To examine the impact of renewable energy on economic growth, the study aims to employ the ARDL developed by Pesaran et al. (2001) and the NARDL approaches proposed by Shin et al. (2014). The ARDL bounds testing approach has advantages over the other cointegration techniques, such as the fact that it can be applied irrespective of whether the variables are integrated of $I(0)$ or $I(1)$. The approach has also been found to be efficient in cases where the sample is small. Moreover, the methodology generally provides unbiased estimates of the long-run model and valid t-statistics, even when some of the regressors are endogenous.

The ARDL model used in this study can be specified as follows:

$$\begin{aligned} \Delta Y_t = & \varphi_0 + \sum_{i=1}^n \varphi_{1i} \Delta Y_{t-i} + \sum_{i=0}^n \varphi_{2i} \Delta RE_{t-i} + \sum_{i=0}^n \varphi_{3i} \Delta INV_{t-i} + \sum_{i=0}^n \varphi_{4i} \Delta L_{t-i} + \sum_{i=0}^n \varphi_{5i} \Delta INT_{t-i} \\ & + \sum_{i=0}^n \varphi_{6i} \Delta TO_{t-i} + \varphi_7 Y_{t-1} + \varphi_8 RE_{t-1} + \varphi_9 INV_{t-1} + \varphi_{10} L_{t-1} + \varphi_{11} INT_{t-1} + \varphi_{12} TO_{t-1} + \mu_{1t} \end{aligned} \quad (2)$$

Where:

φ_0 = constant

$\varphi_1 - \varphi_6$ = short-run coefficients

$\varphi_7 - \varphi_{12}$ = long-run coefficients

Δ = difference operator

n = lag lengths; and

μ_{1t} = white-noise error term

The ECM model associated with the above ARDL model can be expressed as follows:

$$\begin{aligned} \Delta Y_t = & \varphi_0 + \sum_{i=1}^n \varphi_{1i} \Delta Y_{t-i} + \sum_{i=0}^n \varphi_{2i} \Delta RE_{t-i} + \sum_{i=0}^n \varphi_{3i} \Delta INV_{t-i} + \sum_{i=0}^n \varphi_{4i} \Delta L_{t-i} + \sum_{i=0}^n \varphi_{5i} \Delta INT_{t-i} \\ & + \sum_{i=0}^n \varphi_{6i} \Delta TO_{t-i} + \omega_1 ECM + \mu_{2t} \end{aligned} \quad (3)$$

Where:

ECM_{t-1} = lagged error-correction term

ω_1 = coefficient of the lagged error-correction term (ECM_{t-1})

μ_{2t} = white-noise error term

To confirm convergence to long-run equilibrium following a shock or short-term disequilibrium, the coefficient of the error correction term (ω) is expected to be negative and statistically significant.

The NARDL is an extension of the ARDL model that can decompose a variable into positive and negative shocks. Therefore, following Shin et al. (2014), renewable energy (RE_t) can be decomposed into partial sums of positive (RE_t^+) and negative (RE_t^-) changes as follows:

$$y_t = \partial^+ RE_t^+ + \partial^- RE_t^- + X_t + \epsilon_{1t} \quad (4),$$

where:

$$RE_t^+ = \sum_{j=1}^t \Delta RE_j^+ = \sum_{j=1}^t \max(\Delta RE_j; 0) \quad (5),$$

$$RE_t^- = \sum_{j=1}^t \Delta RE_j^- = \sum_{j=1}^t \min(\Delta RE_j; 0) \quad (6),$$

Δ = change,

X = is a set of control variables,

ϵ_{1t} = white noise error term.

The NARDL model based on the above equations can be expressed as follows:

$$\begin{aligned}\Delta y_t = & \omega_0 + \sum_{i=1}^n \omega_{1i} \Delta y_{t-i} + \sum_{i=0}^n \omega_{2i}^+ \Delta RE_{t-i}^+ + \sum_{i=0}^n \omega_{3i}^- \Delta RE_{t-i}^- + \sum_{i=0}^n \omega_{4i} \Delta INV_{t-i} \\ & + \sum_{i=0}^n \omega_{5i} \Delta L_{t-i} + \sum_{i=0}^n \omega_{6i} \Delta INT_{t-i} + \sum_{i=0}^n \omega_{7i} \Delta TO_{t-i} + \varphi_1 y_{t-1} \\ & + \varphi_2^+ RE_{t-1}^+ + \varphi_3^- RE_{t-1}^- + \varphi_4 INV_{t-1} + \varphi_5 L_{t-1} + \varphi_6 INT_{t-1} + \varphi_7 TO_{t-1} + \epsilon_{1t}\end{aligned}\quad (7)$$

Where:

n = optimal lag order,

ω_0 = constant,

$\omega_1 - \omega_7$ = short-run coefficients,

$\varphi_1 - \varphi_7$ = long-run coefficients,

ϵ_{1t} = white noise error term,

t = time period.

Cointegration in a NARDL model setting is ascertained by comparing computed F-statistic to the upper and lower critical bounds from Pesaran *et al.* (2001) critical values. An asymmetric cointegration test is present if the joint null hypothesis, $\varphi_1 = \varphi_2^+ = \varphi_3^- = \varphi_4 = \varphi_5 = \varphi_6 = \varphi_7 = 0$ is rejected.

In the presence of cointegration, an error correction model (ECM) is specified as follows.

NARDL ECM representation

$$\begin{aligned}\Delta y_t = & \omega_0 + \sum_{i=1}^n \omega_{1i} \Delta y_{t-i} + \sum_{i=0}^n \omega_{2i}^+ \Delta RE_{t-i}^+ + \sum_{i=0}^n \omega_{3i}^- \Delta RE_{t-i}^- + \sum_{i=0}^n \omega_{4i} \Delta INV_{t-i} \\ & + \sum_{i=0}^n \omega_{5i} \Delta L_{t-i} + \sum_{i=0}^n \omega_{6i} \Delta INT_{t-i} + \sum_{i=0}^n \omega_{7i} \Delta TO_{t-i} + \gamma ECM_{t-1} + \epsilon_{2t}\end{aligned}\quad (8)$$

Where:

γ = coefficient of the error term,

ECM = error correction term.

The existence of long-run and short-run symmetry is tested using the Wald test with the null and alternative hypothesis to test the presence of long-run asymmetry expressed as follows:

$$H0: -\varphi_2^+ / \varphi_1 = -\varphi_3^- / \varphi_1$$

$$H1: -\varphi_2^+ / \varphi_1 \neq -\varphi_3^- / \varphi_1$$

The null and alternative hypothesis to test the presence of short-run asymmetry is expressed as follows:

$$H0: -\omega_{2i}^+ / \omega_{1i} = -\omega_{3i}^- / \omega_{1i}$$

$$H1: -\omega_{2i}^+ / \omega_{1i} \neq -\omega_{3i}^- / \omega_{1i}$$

5. Empirical results and discussion

Although the ARDL approach does not require all variables to be integrated of the same order [i.e., $I(1)$], the technique cannot be used if any of the variables is integrated of order two or higher. Consequently, it is important to conduct a unit root test to ensure that no variable is integrated of order two or higher. To determine the order of integration, the study uses two stationarity techniques, namely, the Dickey-Fuller Generalised Least Square (DF-GLS) and Phillips-Perron (PP) tests. The results of the unit root tests are, therefore, reported in Table 2.

Table 2. Stationarity test for all variables - DF-GLS and Phillips-Perron (PP).

Variable	DF-GLS		PP		Decision
	Level	Δ	Level	Δ	
<i>y</i>	-2.073	-7.449***	-3.047	-8.477***	I(1)
<i>RE</i>	-2.550	-6.335***	-3.278*	—	I(0) I(1)
<i>INV</i>	-2.202	-4.404***	-1.527	-3.981***	I(1)
<i>L</i>	-1.847	-5.181***	-2.067	-5.006***	I(1)
<i>INT</i>	-4.864***	—	-7.315***	—	I(0)
<i>TO</i>	-2.590	-3.942***	-1.458	-4.606***	I(1)

Notes: * and *** denotes stationarity at, 10% and 1% significance level, Δ is first difference.

Table 3. Long- and short-run asymmetry results.

Test	F-statistic	p-value	Decision
W_{LR}	0.085	0.776	symmetric
W_{SR}	0.043	0.840	symmetric

Notes: W_{LR} is long-run asymmetric test; W_{SR} is short-run asymmetric test.

Table 4. Cointegration results.

Model	F-Statistic	Asymptotic critical values					
		10%		5%		1%	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
ARDL	7.547***	2.26	3.35	2.62	3.79	3.41	4.68

Note. *** denote statistical significance at 1% level.

The results reported in Table 2 clearly show that no variable is integrated of order two [i.e., I (2)] or higher. Hence, we can proceed with the ARDL and NARDL approaches to examine the relationship between renewable energy and economic growth.

However, before we employ the NARDL approach, it is essential to examine whether the relationship between renewable energy and economic growth in Namibia is symmetric or asymmetric using the Wald test. The results of the asymmetric test based on the Wald test are reported in Table 3.

The results reported in Table 4 show that there is no asymmetric relationship between renewable energy and economic growth in the study country. Since it has been established that there is no asymmetric relationship between renewable energy and economic growth in Namibia, the study will only estimate the linear ARDL and not the non-linear ARDL. The results of the bounds test for cointegration based on the linear ARDL is reported in Table 4.

The cointegration test results reported in Table 4 show that there is a long-run relationship between economic growth and the explanatory variables. This has been confirmed by the F-statistic of 7.547, which is higher than the upper bound F-statistic at 1%. Since the variables have been found to be cointegrated, we can proceed to examine the short-run and long-run relationship between economic growth, renewable energy, and other regressors using the ARDL. The results of the linear ARDL are, therefore, reported in Table 5.

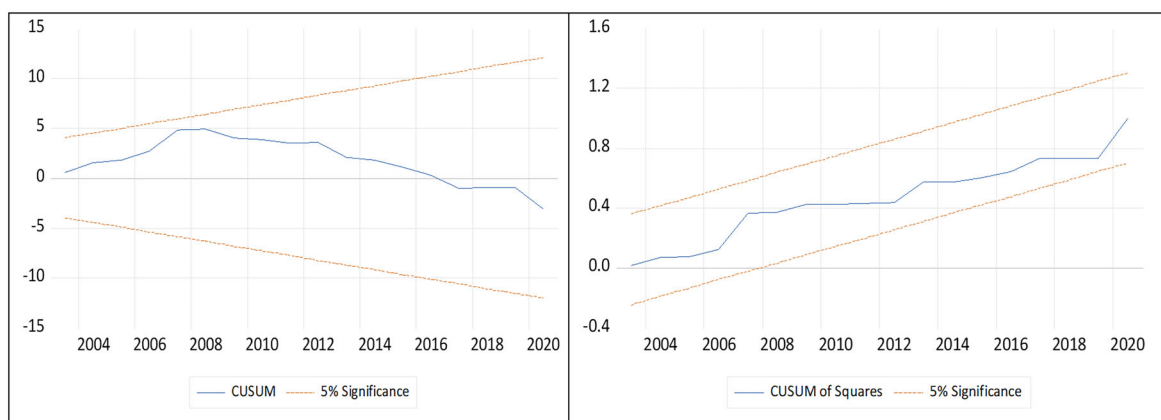
The results reported in Table 5 show that renewable energy has a positive impact on economic growth in both the long and short run. This is confirmed by the coefficient of renewable energy, which is positive and statistically significant at 1%. The findings confirm that renewable energy consumption contributes to the growth of the Namibian economy. The findings are similar to other studies such as Charfeddine and Kahia (2019) for 24 countries of the Middle East and North Africa, Haseeb et al. (2019) for Malaysia and Khobai and Le Roux (2017) among others, who have found the relationship between renewable energy and economic growth to be positive. This finding is not surprising given the level of investment in non-renewables in Namibia. As stated in the policy documents, Namibia intends to expand its renewables to account for 60% of its electricity generation by 2035.

The results for the control variables show that investment has a positive impact on economic growth in both the long run and short run. The results are consistent with findings from other studies, such as Anaman (2004) and Acikgoz and Mert (2014). This means that investment contributes to Namibia's

Table 5. ARDL long-run and short-run results.

Long-run results: Dependent variable is y		
Regressor	Coefficient	T-ratio [p -value]
RE	1.345**	2.397 [0.028]
INV	1.031***	3.276 [0.004]
L	-1.971**	-2.220 [0.040]
INT	-1.246	-1.675 [0.111]
TO	-0.279**	2.140 [0.046]
Short-run results: Dependent variable is Δy		
C	57.293***	7.525 [0.000]
ΔRE	0.946***	3.085 [0.006]
ΔINV	0.725***	4.106 [0.001]
ΔL	-1.386***	-4.008 [0.001]
ΔINT	0.032	0.382 [0.707]
$\Delta INT (-1)$	0.506***	5.470 [0.000]
ΔTO	-0.452***	-6.641 [0.000]
$ECM(-1)$	-0.703***	-7.607 [0.000]
R-Squared	0.756	
R-Bar-Squared	0.713	
Normality	1.332 [0.514]	
Serial Correlation	2.030 [0.164]	
Heteroscedasticity	0.963 [0.499]	

Notes: ** and *** denote statistical significance at 5% and 1% levels, respectively.

**Figure 2.** Plot of CUSUM and CUSUMQ.

economic growth. Although not consistent with the theory, labour was found to have a negative impact on economic growth in the short run and long run. This is confirmed by the coefficient of labour variable, which is negative and statistically significant. Interest rate is found to have no impact on economic growth in Namibia in the long or short run. However, in the short run, the interest rate in the previous period was found to have a significant positive impact on economic growth. The results also show a negative and highly statistically significant relationship between trade openness and economic growth in the short run and long run. Although it is unexpected, Musila and Yiheyis (2015) also found that trade-policy induced openness has a negative and significant effect on the rate of economic growth in Kenya, while Polat et al. (2015) found that trade openness impedes economic growth in South Africa.

The coefficient of the error term lagged by one period, is negative, as expected, and statistically significant at the 1% level of significance. This implies that economic growth would return to equilibrium at a rate of 70.3% per annum in the event of a shock in the economy.

The model diagnostic tests for normality, serial correlation and heteroscedasticity are also presented in Table 5. These diagnostic test results indicate that the model residuals are normally distributed and that there is no serial correlation or heteroscedasticity. The cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) plots are presented in Figure 2. The CUSUM and CUSUMQ indicate that the model is stable, as the plots are within the confidence band at 5% level of significance.

6. Conclusion

The paper investigated whether renewable energy has an asymmetric or symmetric impact on economic growth in Namibia using annual data from 1990 to 2020. The study was motivated by the growing importance of renewable energy in the economic growth process of many economies, yet Namibia remains without coverage. Further, knowing whether this relationship is linear or not is crucial for policy formulation purposes, yet no such information is known for Namibia. The data was first subjected to stationarity tests before the analysis was conducted. After the stationarity was confirmed, the Wald test was used to examine the existence of short-run and long-run asymmetries between renewable energy and economic growth in the study country. The results of the Wald test confirmed that the relationship between renewable energy and economic growth is symmetric. Therefore, the study continued with the estimation of the ARDL model. The results of cointegration tests confirmed that there is a long-run relationship among the variables in both models. The ARDL results show that renewable energy has a positive and significant impact on economic growth in both the long and short run. The results confirm that renewable energy consumption does contribute to the growth of the Namibian economy. This also shows that renewable energy can enable the country to achieve higher economic growth. To increase the use of renewable energy, the government and policymakers should develop renewable energy policies as it will not only reduce carbon emissions but will also stimulate the economy. The government should also develop incentives for businesses and citizens to promote the use of renewable energy. Moreover, since the government aims to expand its renewables to account for about 60% of total electricity generation by 2035, it is imperative that the government continues with the implementation of policies that can enable the country to explore renewable energy from sources such as photovoltaics, wind power, biomass, and concentrated solar power.

Authors' contributions

Dr Glenda Maluleke, Prof Nicholas M. Odhiambo and Dr Sheilla Nyasha all participated in conducting the study. Dr Glenda Maluleke made contributions to methodology and data analysis, interpretation of the results. Prof Nicholas M. Odhiambo made contributions to conceptualization, the drafting of the paper, revising it critically for intellectual content. Dr Sheilla Nyasha contributed significantly to the literature review and revising it critically for intellectual content. All the three authors approved the final version to be published and agreed to be responsible for all aspects of the work published.

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Data availability statement

The data that support the findings of this study are openly available at <https://databank.worldbank.org/source/world-development-indicators#>

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