The Dynamic Impact of Renewable Energy Consumption on Economic Growth in Zimbabwe: An ARDL Approach

Sheilla Nyasha
University of South Africa, South Africa
sheillanyasha@gmail.com

Motivated by the study country's active involvement in the reduction of global greenhouse gas emissions and the positive strides it has made domestically in increasing renewable energy in its energy mix, on the one hand, and the need to find out whether renewable energy consumption can also assist in reviving the economy, on the other hand, this study empirically examines the dynamic impact of renewable energy consumption on economic growth in Zimbabwe. Using annual time-series data from 1990 to 2019, and the autoregressive distributed lag approach, the results of the study show that in Zimbabwe, renewable energy consumption has a positive impact on economic growth, both in the short and long run. Increasing the usage of renewable energy increases the growth of the economy in the country of study. These results imply that Zimbabwe can achieve two goals using one strategy – increasing renewable energy consumption to decrease the negative impact climate change and greenhouse gas emission have on the environment and the economy, and increasing economic growth. Policy makers in Zimbabwe are, therefore, recommended to support increased use of renewable energy over alternative energy sources, as this would have positive implications on the economy, both in the short and long term.

Key Words: renewable energy consumption, energy mix, economic growth, Zimbabwe, impact
JEL Classification: O40, Q40

Received 2023/02/06 · Revised 2023/04/12 · Accepted 2023/04/14
Published online 2024/03/31 https://doi.org/10.26493/1854-6935.22.53-72

Introduction

Renewable energy has turned overnight into a buzzword among researchers and policy makers alike as they seek solutions to global warming threats in particular, and to climate change in general. It has become generally accepted that there is no path to protecting the climate without dramatically changing how energy is produced and consumed (United Nations 2021). The new dawn is now ushering in renewable energy as the gateway to reduced greenhouse gas emissions, and minimisation of climate change and its global impact.

Just like many other countries, Zimbabwe has also been negatively affected by climate change shifts and challenges, resulting in increased occurrences of severe droughts and floods arising from cyclones (United Nations 2021). As part of a joint force, according to All Africa (2022), Zimbabwe has pledged to reduce greenhouse emissions by 2030 and has set a target to have 2000 megawatts of energy produced from renewable sources by the year 2030. The country also tabled this bold national position before the Conference of the Parties (COP) 26 in Glasgow, United Kingdom in 2021 (All Africa 2022). Given all this national effort, the question for any development economist is whether renewable energy production and consumption is only good for climate change and greenhouse gaseous emission control or if there is more to it.

As the country battles to revive its ailing economy, could the consumption of renewable energy lead to economic growth as well in Zimbabwe? As simple as this question may appear, its answer is not straightforward. The nexus between renewable energy use and economic growth is a concept little explored, but a review of empirical literature leaves one confused as to what renewable energy consumption could hold for Zimbabwe, as divergent views are revealed. To be specific, three views have emerged where the impact of renewable energy consumption on economic growth has been empirically investigated. The first view posits that renewable energy consumption is good for economic growth (see Majeed, Anwar, and Luni 2021; Charfeddine and Kahia 2019; Haseeb et al. 2019), while an alternative view postulates the opposite (see Venkatraja 2020; Smolović et al. 2020; Tsaurai and Ngcobo 2020). Then, the third view suggests that renewable energy use does not impact significantly on economic growth (see Smolović et al. 2020; Nyoni and Phiri 2018; Dogan 2016). The lack of consensus on the subject makes it impossible to predetermine whether the influence of renewable energy use on economic growth in Zimbabwe is positive, negative or neutral – calling for a study on Zimbabwe to unravel the relationship between the two variables in the country. The closest there is, is a study by Hlongwane and Daw (2022). However, the study was narrower in scope as it focused on the impact of renewable electricity consumption on economic growth –

where renewable electricity is only a subset of the total renewable energy consumption.

Given this backdrop, the objective of this study is to investigate, empirically, the impact of renewable energy consumption on economic growth in Zimbabwe, in an effort to unravel whether renewable energy consumption can be useful in more ways than one – combatting climate challenges and directly growing the economy. The study uses data from 1990 to 2019 and the autoregressive distributed lag (ARDL) methodology to uncover this renewable energy-growth nexus. This method is chosen because of advantages it has over the other orthodox methods, hence the results are expected to be robust. The outcome of the study is expected to have key policy implications specific to Zimbabwe and will also contribute to the body of knowledge as it assists in providing a step towards the conclusion of the current debate.

The study is organised into six sections. The second section provides highlights of the renewable energy landscape and economic growth trends in Zimbabwe, while the third and fourth sections present the literature review and methodology, respectively. Data analysis, presentation and discussion of results is covered in the fifth section, leaving the sixth and last section to conclude the study.

Renewable Energy Landscape and Economic Growth Trends in Zimbabwe

According to Mordor Intelligence (2022), Zimbabwe is among the countries with the fastest-growing energy markets in Africa. Its electricity generation prospects from various renewable energy sources have also been highlighted (Mordor Intelligence 2022). The prominent sources indicated include biomass and hydro, as well as solar, energy. However, despite this potential, realisation of such power has been a challenge. In 2020, less than half of the population in the country had access to electricity. Mordor Intelligence (2022) put this group with access at about 41.09%, acknowledging that it is the urban population that occupies the greater portion of this percentage, leaving 19% for rural electricity access.

In an effort to join hands with the globe in combatting the fast deteriorating climate and carbon emissions at both domestic and global levels, the country has pushed itself and set a high target of renewable energy capacity increase (Mordor Intelligence 2022). In 2019, the government of Zimbabwe crafted and implemented a National Renewable Energy

Policy (NREP) with various renewable energy-related targets (Ministry of Energy and Power Development 2019). These targets include achieving 16.5% of the total energy generation capacity from renewables by 2025. The target is to increase this to 26.5% in five years, i.e. by 2030. Greenhouse gas emissions have also been targeted to be reduced by 33% by 2030, while the ethanol blending ratio has been set to decline by 20% over the same period (Ministry of Energy and Power Development 2019; Mordor Intelligence 2022). Such a policy is expected to propel the market for renewable energy in the study country across the short-, medium- and long-term horizons.

In 2022, according to the Zimbabwe Energy Regulatory Authority (Zimbabwe Energy Regulatory Authority N. d.) and Mutasa (2022), the bulk of Zimbabwe's energy supply mix is made up of hydropower, about 68.17%, while the remainder is from coal and other sources of renewable energy. Anchored on the NREP of 2019, Zimbabwe's renewable energy space has seen heightened activity by independent power producers (IPPS) recently as they explore alternative sources of energy. The outcome has not only been an increase in the mix of the renewable energy within the country's energy mix, but has also resulted in the creation of economic opportunities as IPPS have generated incentives in the renewable energy value chain in towns and rural villages – from supply and distribution and demand nodes (Mutasa 2022).

Zimbabwe's efforts to green and reduce the carbon footprint has been consistent, not only on the national front but also on the global level. According to All Africa (2022), Zimbabwe announced its target of 2000 megawatts of renewable energy production by 2030 at the COP26 gathering in Glasgow as part of its efforts to significantly cut down carbon emission by the same date. Due to constant power outages, solar energy investments have been sizeable in the country, which saw an increase in off-grid electricity demand by residents being met by solar home systems that are standalone (All Africa 2022).

Although there has been notable commitment from the government of Zimbabwe to push the renewable energy agenda, numerous challenges mar the renewable energy landscape in Zimbabwe. These include delays in carrying out projects in the renewable energy space due to competing priorities on the identified land; policy inconsistencies regarding the issuance of licences and regulation of such projects; Power Purchase Agreements that are expressed in local currency and currency fluctuations that tend to affect these agreements; elevated costs of production affecting the economic feasibility and sustainability of renewable energy projects, a challenge which is exacerbated by the less competitive renewable energy production market currently dominated by five companies – which has implications on the affordability of renewable energy and consumption thereof; and climate change, which has led to persistent droughts that have the effect of easing the capacities of power generation across hydro power plants in the country, with the Kariba Hydro Station being the most affected (Zimbabwe Energy Regulatory Authority N. d.; Mutasa 2022).

Economic growth-wise, Zimbabwe's economy has been ailing for some time. According to the African Development Bank (African Development Bank Group N. d.), the COVID-19 pandemic found Zimbabwe's economy waning already, contracting by 6.0% in 2019. An unstable economy, as well as the scrapping of a number of subsidies such as those on electricity, fuel and mealie meal and stifled foreign exchange earnings, coupled with extreme money creation, led to the plunge in output. On the back of COVID-19 and its effects, and constant droughts, real gross domestic product (GDP) dipped by 10% in 2020 (African Development Bank Group N. d.). The World Bank Group (2022) has also weighed in, adding resource misallocation, limited and narrow structural transformation, sky-rocketing costs of production, a hyper inflationary environment and depressed investment – both domestic and foreign direct – to the list of Zimbabwe's economic development woes.

Despite these challenges, economic growth significantly rebounded in 2021 by 8.5% (World Bank Group N. d.), most likely due to base effect as the economy recovered from the sharp plunges in economic growth during the COVID-19 period. Following a growth stint in 2021, the World Bank Group (N. d.) projects Zimbabwe's growth of real GDP to ease to 3.4% in 2022, because of economic activity that slackened in 2022, amid agricultural conditions that worsened and price volatility. Figure 1 shows trends in renewable energy consumption for Zimbabwe, expressed as a percentage of total energy consumption, and economic growth, proxied by the growth rate of real GDP, during the study period.

As shown in Figure 1, there has been a consistent increase in renewable energy consumption from 63.7% in 1990 to 81.5% of total energy consumption in 2019 (World Bank Group N. d.), which is evidence of an appreciation of clean energy, on the one hand, and a quest by economic agents to find a reliable source of energy, on the other hand, in the wake of prolonged blackouts that have negatively affected production

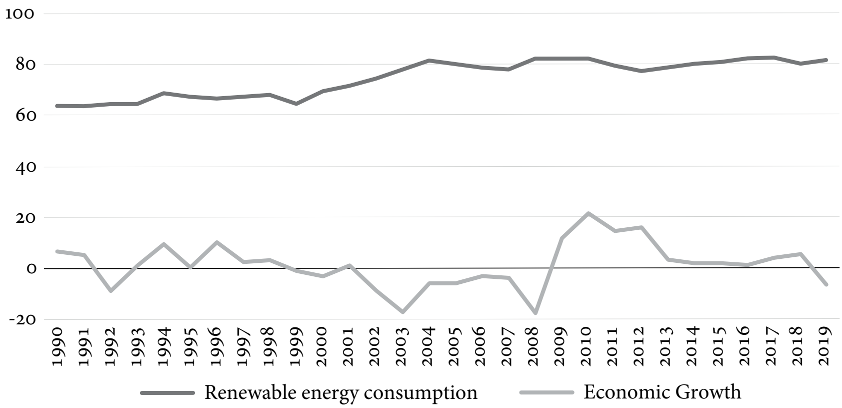

FIGURE 1 Renewable energy consumption and economic growth trends in Zimbabwe (1990-2019)
SOURCE World Bank Group (N. d.)

and household daily activities. By any standard, having more than 80% renewable energy consumption is a great achievement.

However, the consistent increase in the use of renewable energy is not mimicked by the growth in the economy of Zimbabwe. Although unusual, this should not be surprising given the economic woes the country is facing; and it can be argued that without increased usage of renewable energy, it could have been worse. Despite its volatility over the review period, in the main, the economic growth has been trending upwards, albeit with a far less steep slope, as reflected by the economic growth linear trend in Figure 1.

Literature Review

Studies on the impact of renewable energy consumption on economic growth are scanty though mounting. A review of empirical literature regarding the impact of renewable energy use on the growth of the economy reveals that besides being still nascent, the existing literature is far from being conclusive. Three categories have emerged – those studies that found a positive contribution of renewable energy use to economic growth, then those that found a negative impact of renewable energy use on economic growth, and lastly, those studies that found renewable energy to be neutral.

Majeed, Anwar, and Luni (2021) investigated the impact of renewable energy on economic growth for 174 economies using panel data spanning from 1980–2019. The sample was divided into two categories – developed economies and developing economies, and renewable energy consumption data was disaggregated according to the production sources. Employing panel estimation, the study found renewable energy to contribute to economic growth. These results were consistent across developed and developing country groups, showing the importance of renewable energy irrespective of the level of economic development. The outcome of the study was similar to that of Charfeddine and Kahia (2019) and Haseeb et al. (2019).

Charfeddine and Kahia (2019) analysed the impact of renewable energy utilisation on economic growth, the development of the financial system and carbon dioxide production for 24 countries in North Africa and the Middle East. The study used data from 1980–2015 and the panel vector autoregressive model. The findings of the results revealed a positive contribution of the utilisation of renewable energy to the growth of the economies under study. Haseeb et al. (2019) found the same results for Malaysia using data covering 1980–2016.

Kamoun, Abdelkafi, and Ghorbel (2019) put to empirical test the nexus between renewable energy use on sustainable growth for Organisation for Economic Co-operation and Development (OECD) economies using data for the 1990 to 2013 period. The findings from the study corroborated the results from the previous studies, affirming the positive contribution of renewables to economic growth. In a separate study, Rafindadi and Ozturk (2017) examined the impact of renewable energy usage on economic growth for Germany using quarterly data from 1971 to 2013. Employing the ARDL procedure, Clemente-Montanes-Reyes detrending structural breaks and Bayer-Hanck cointegration test, the study found renewable energy usage to have a positive impact on economic growth, boosting it by 2.2% for every 1% increase in the consumption of renewable energy.

Cetin (2016) examined the impact of renewable energy consumption on economic growth for seven emerging economies, employing data from 1992 to 2012. Using heterogenous panel data analysis, the study found renewable energy consumption to influence economic growth positively. In the same spirit, Inglesi-Lotz (2016) did a study on the impact of renewable energy on economic welfare in OECD countries using panel data. The study found that increasing renewable energy use leads to the improvement of economic welfare in the study countries.

Besides empirical literature attesting to the positive impact of renewable energy on economic growth, there is a strand of literature that found the consumption of renewable energy to negatively affect economic growth. For example, Hlongwane and Daw (2022), who examined the relationship between renewable electricity consumption for South Africa as well as Zimbabwe using data of time-series nature covering the 1990–2019 period. Using the ARDL-based methodology, the results of the study found renewable energy to negatively affect economic growth in both countries in the short run. However, in the long run, renewable energy proved to have the same effect on the economy of South Africa only.

Venkatraja (2020), in a study on the impact of renewable energy use on economic growth in the case of BRIC countries – Brazil, Russia, India and China – using data from 1990–2015 and panel regression, confirmed a negative association between renewable energy use and economic growth. The same finding was established by Smolović et al. (2020) and Tsaurai and Ngcobo (2020) in separate studies on EU member states and BRICS countries, respectively. The two studies found a negative contribution of renewable energy utilisation to the growth of the economies, supporting the same findings by Venkatraja (2020). Matei (2017) also put to the test the effect of using renewable energy on economic growth in the case of 34 OECD economies. The period of study was from 1990 to 2014. The study also found that using renewable energy negatively influences the real economy.

The last strand of literature found renewable energy consumption to have a neutral effect on economic growth. For example, Hlongwane and Daw (2022) for Zimbabwe, in the long term. Smolović et al. (2020) also assessed the relationship between renewable energy consumption and economic performance for EU member states using data from 2004–2018 and established that renewable energy use has a neutral impact on economic growth, but only in traditional member states. Nyoni and Phiri (2018) also found the same results in a separate study on South Africa using data from 1991–2016 and linear and non-linear ARDL models; so did Dogan (2016) based on Turkish regional data, and Ocal and Aslan (2013) based on Turkish national data. Although this strand is still unpopular, of late, it has been gaining visibility.

From the reviewed literature, it can be concluded that despite the little harmony on the impact of renewable energy on the economic growth process, overall, empirical literature is in favour of renewable energy use having a positive influence on economic growth. Nonetheless, even at that, it is also prudent to recognise that the presence, in literature, of the evidence suggesting otherwise, albeit thin, requires an assumption that 'renewable energy consumption has a positive impact on economic growth' to be taken with a pinch of salt. Though predominantly positive, the impact of renewable energy consumption on economic growth has been found to vary depending on the country or region of study and on the methodology used – with most studies utilising cross sectional and panel methodologies, even though it is known that such methods pay less attention to country-specific effects. This exposes a gap in the literature that requires filling through further research on the subject in specific jurisdictions of interest – in this case, Zimbabwe.

Methodology

ARDL BOUNDS TESTING APPROACH

The autoregressive distributed lag (ARDL) bounds testing approach is utilised in this study to empirically examine the impact of renewable energy consumption on economic growth in Zimbabwe. This approach was originally developed by Pesaran and Shin (1999). However, it was later refined by Pesaran, Shin, and Smith (2001). The rationale for using this method is based on the various advantages it offers compared to the orthodox approaches (Engle and Granger 1987; Johansen and Juselius 1990).

The ARDL procedure is well known for its flexibility, yet with robust outcomes (Nyasha and Odhiambo 2019). It does not foist the limiting condition that all the study variables should have the same order of integration, allowing the application of the ARDL bounds testing procedure even when some variables are integrated of order zero while others are of order one (Nyasha and Odhiambo 2015; 2019). Furthermore, the chosen method of data analysis is executed in a simpler way as it is centred on a single reduced form equation as compared to the more complicated conventional procedures that utilise a system of equations to estimate relationships between variables (Duasa 2007; Nyasha and Odhiambo 2020; Nyasha, Odhiambo, and Musakwa 2022). With the ARDL bounds test, the endogeneity problem is automatically resolved. The method provides unbiased long-run model estimates as well as valid t-statistics even in the cases where some of the independent variables could be endogenous (Nyasha and Odhiambo 2020).

Whereas other orthodox cointegration methods are sensitive to the sample size, the ARDL approach is appropriate and still yields robust results even when the sample size is small (Pesaran and Shin 1999; Nyasha and Odhiambo 2022). Thus, the chosen method has superior small sample properties, a trait which makes this approach to data analysis plausible given the limited data points of the series utilised in this study. Based on these offerings, the ARDL bounds testing approach is, therefore, considered the most appropriate method of analysis of the underlying relationships as the study seeks to explore the impact of renewable energy consumption on economic growth in Zimbabwe. Over the years, the method has also gained traction, pointing to its effectiveness over other conventional methods.

SPECIFICATION OF THE EMPIRICAL MODEL

In this study, economic growth (y) is the dependent variable, proxied by the annual growth rate of real GDP. The measure has been utilised expansively in past studies (see Nyasha and Odhiambo 2015; 2019; Asongu and Diop 2022). Meanwhile, renewable energy consumption (RECON) is proxied by the amount of the renewable energy that is consumed as a proportion of the total energy consumed (Arzova and Sahin 2023; Nyasha and Odhiambo 2022; El-Karimi 2022; Sahin and Yilmazer 2021). This indicator shows the overall extent to which renewable energy is used within a country as a source of energy. According to Majeed, Anwar, and Luni (2021) and Charfeddine and Kahia (2019), renewable energy consumption has a positive effect on economic growth. Therefore, the coefficient of this variable is expected to be statistically significant, and positive.

To fully specify the growth model, and to ensure that the results do not suffer from the variable omission bias, three more variables – control variables – are added. These are domestic investment, trade openness and labour force. Investment is measured by the share of gross fixed capital formation on GDP (GF). According to Nyasha and Odhiambo (2015) and Abu-Bader and Abu-Qarn (2008), among others, this variable is regarded as one out of a handful of economic variables robustly correlated with economic growth, and a positive coefficient is anticipated.

Trade openness (TR) is another control variable utilised in this research. It is measured by the summation of imports and exports as a percentage of GDP. The relationship between trade openness and the growth of the economy is fully recognised and well documented in the literature (Ang and McKibbin 2007; Nyasha and Odhiambo 2017). The coefficient of trade openness is envisaged to be positive and statistically significant.

The third control variable utilised is labour force (LF). It is measured by total labour force participation rate expressed as a percentage of total population aged 15 years and above. The proxy has been used widely in energy consumption and economic growth studies (Zeshan and Ahmad 2013; Saad and Taleb 2018). While it is associated with economic growth, it has been identified as a better measure than employment and population in estimating the renewable energy use in an economy as energy use is a function of affordability, among others. The bigger the labour force, the more renewable energy is consumed and the faster the economy is expected to grow (see Young 2018), hence the coefficient of labour force is anticipated to be positive and significant.

Therefore, the empirical model adopted in this study to examine the effect of renewable energy consumption on economic growth in the study country is specified as follows:

$$y_t = \delta_0 + \delta_1\, RECON_t + \delta_2\, GF_t + \delta_3\, TR_t + \delta_4\, LF_t + \varepsilon_t \tag{1}$$

where y is GDP annual growth rate, a proxy for economic growth; RECON is renewable energy consumption expressed as a proportion of total energy consumption; GF is share of domestic investment in GDP; TR is trade openness, proxied by the share of the summation of imports and exports in GDP; and LF is labour force, which is total labour force participation as a percentage of the total population aged at least 15 years; δ_0 is a constant; δ_1- δ_4 are coefficients; while ε_t is the error term.

ESTIMATION TECHNIQUE – THE ARDL MODEL

Following Pesaran, Shin, and Smith (2001) and Nyasha and Odhiambo (2015; 2022), the ARDL representation of the estimated model (Equation 1) is expressed as follows:

$$\begin{aligned}\Delta y_t = {} & \delta_0 + \sum\nolimits_{i=1}^{n} \delta_{1i} \Delta y_{t-i} + \sum\nolimits_{i=0}^{n} \delta_{2i} \Delta RECON_{t-i} \\ & + \sum\nolimits_{i=0}^{n} \delta_{3i} \Delta GF_{t-i} + \sum\nolimits_{i=0}^{n} \delta_{4i} \Delta TR_{t-i} \\ & + \sum\nolimits_{i=0}^{n} \delta_{5i} \Delta LF_{t-i} + \delta_6 y_{t-1} \\ & + \delta_7 RECON_{t-1} + \delta_8 GF_{t-1} + \delta_9 TR_{t-1} \\ & + \delta_{10} LF_{t-1} + \mu_t ,\end{aligned} \tag{2}$$

where δo is a constant; $\delta 1$- $\delta 5$ and $\delta 6$- $\delta 10$ are coefficients – short-run and long-run, respectively; Δ is the difference operator, n is the lag length, and μ_t is the white noise-error term. All the other variables are as defined in Equation 1.

The ARDL-based error-correction model associated with Equation 2 is as follows:

$$\Delta y_t = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta y_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta RECON_{t-i} + \sum_{i=0}^{n} \delta_{3i} \Delta GF_{t-i} + \sum_{i=0}^{n} \delta_{4i} \Delta TR_{t-i} + \sum_{i=0}^{n} \delta_{5i} \Delta LF_{t-i} + \delta_{11} ECM_{t-1} + \mu_t, \quad (3)$$

where ECM is the error-correction term; is the coefficient of the error-correction term; μ_t = mutually uncorrelated white-noise residuals; and all other variables and characters are as defined in Equations 1 and 2.

DATA SOURCES

The study utilises annual time series data from 1990 to 2019. All the data is collected from the World Bank Economic Indicators (World Bank Group N. d.).

Results: Presentation and Analysis

STATIONARITY TESTS

To establish whether the variables in the study are not integrated of order two or higher – a condition which nullifies the use of the ARDL bounds test approach – all the variables are tested for stationarity. To this end, two tests are employed, the Dickey-Fuller Generalised Least Square and the Phillips-Perron unit root tests. The results are summarised in Table 1.

As reflected in Table 1, the variables in the study are found to be stationary, either in levels or in first difference, depending on the unit root test used and whether an intercept only or both intercept and trend are included in the tests. The results confirm the applicability of the chosen estimation procedure – the ARDL bounds testing approach.

COINTEGRATION

Having confirmed that all the variables are integrated of order one or zero, cointegration tests are carried out to examine whether there exists a long-run stable relationship among the variables in the specified model. Table 2 presents the cointegration results for this study.

TABLE 1 Results of the Stationarity Tests

Variable	Dickey-Fuller generalised least square				Phillips-Perron			
	Variables in levels		Variables i n 1st difference		Variables in levels		Variables in 1st difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend
Y	-3.185***	-3.214**	-	-	-3.195**	-3.156	-	-6.845***
RECON	-0.636	-1.803	-4.951***	-5.023***	-1.208	-1.812	-4.937***	-5.012***
GF	-2.111**	-2.691	-	-7.164***	-2.154	-2.661	-7.168***	-7.013***
TR	-2.340**	-2.806	-	-8.468***	-2.903*	-2.941	-	-8.151***
LF	-1.746*	-2.234	-	-3.785***	-0.623	-1.186	-2.776*	-3.615**

NOTES *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

As shown in Table 2, the calculated F-statistic of 4.41 is greater than the upper bound critical value of 4.01 at the 5% significance level. Based on these results, the null hypothesis of no cointegration cannot be accepted; therefore, it is concluded that a long-run stable relationship exists between the variables in the specified model. This confirmation allows the study to proceed to the next level, allowing for the assessment of the coefficients of the specified model, both in the long and short run.

ESTIMATION OF COEFFICIENTS – ARDL APPROACH

Following the confirmation of cointegration, the long-run and the short-run coefficients are estimated based on the ARDL estimation procedure. The optimal lag-length for the specified model is selected manually as the resultant model is more parsimonious than the Akaike Information Criterion- and the Schwarz Information Criterion-based models. The lag-length selected, based on its optimality, is ARDL(1,1,0,2,0). The results of the selected model are presented in Table 3.

As displayed in Table 3, in both panels, the regression results show that the coefficient of renewable energy consumption is statistically significant and positive, as expected. This suggests that in Zimbabwe, renewable energy utilisation has a positive impact on economic growth. An increase in the consumption of renewable energy in Zimbabwe results in increased economic growth. These results are found to be valid regardless of whether estimation is in the long run or short run. While the long-run positive impact is evidenced by the coefficient of renewable energy consumption (RECON) in Panel 1, the short-run positive impact is validated by the coefficient of renewable energy consumption (ΔRECON)

TABLE 2 Results of Cointegration Test

Dependent Variable	Function	F-statistic	Cointegration Status
y	F(y | RECON, GF, TR, LF)	4.41**	Cointegrated

Asymptotic Critical Values

Pesaran, Shin, and Smith (2001), p. 300, Table CI(iii)	10%		5%		1%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Case III	2.45	3.52	2.86	4.01	3.74	5.06

NOTE ** denotes statistical significance at 5% level. ΔTR1 = TR(-1)-TR(-2)

TABLE 3 Empirical Results of the Estimated ARDL Model

Panel 1: Estimated long-run coefficients [Dependent variable: y]

Independent variable	Co-efficient (t-statistic)
C	-22.420 (0.385)
RECON	0.591** (2.040)
GF	0.982*** (3.740)
TR	0.265* (1.855)
LF	0.580 (0.155)
Panel 2: Estimated short-run coefficients [Dependent variable: Δy]	
ΔRECON	0.287* (1.762)
ΔGF	0.985*** (3.688)
ΔTR	0.217 (1.427)
ΔTR1	0.307** (2.463)
ΔLF	0.528 (0.152)
Ecm (-1)	-0.911*** (-4.624)

NOTE R-Squared 0.707 R-Bar-Squared 0.684. SE of Regression 6.180 F-Stat F(6,21) 7.648[0.000]. Residual Sum of Squares 725.685 DW statistic 2.143. *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

in Panel 2, that is both statistically significant and positive. These results are consistent with the literature – both theoretical and empirical (see Kamoun, Abdelkafi, and Ghorbel 2019; Charfeddine and Kahia 2019; Cetin 2016). These results could be a reflection that the efforts by the Zimbabwean Government on the renewable energy front are not in vain.

The other results in Table 3 reveal that in Zimbabwe, domestic investment (GF), just like the consumption of renewable energy, has a positive effect on economic growth – both in the long and short run. Trade openness is also found to have a positive impact on economic

TABLE 4 Diagnostic Tests

LM Test Statistic	Results [Probability]
Serial Correlation: CHSQ (1)	1.937 [0.164]
Heteroscedasticity: CHSQ (1)	0.114 [0.736]
Functional Form: CHSQ (1)	0.377 [0.539]
Normality: CHSQ (2)	0.739 [0.691]

NOTE CHSQ = Chi-square

growth in the study country, both in the long run and in the short run. These results imply that in the study country, increasing domestic investment and foreign trade leads to an increase in economic growth, irrespective of whether it is in the long run or in the short run. However, in the short run, it is trade openness in previous periods that is found to matter positively in the economic growth process of Zimbabwe. Contrary to expectations, labour force is found to be neutral in both time periods, implying that in Zimbabwe, the size of the labour force does not matter as labour force does not exert any significant impact on economic growth in Zimbabwe. As expected, the coefficient of the error correction term [ECM (-1)] emerged negative and significant. Should a shock occur in Zimbabwe, the results indicate that the equilibrium is restored in just over a year, at a rate of 91% per annum.

The regression of the model was found to fit well, as highlighted by R-squared of 70.7%, indicating that about 70.7% of the economic growth dynamics in Zimbabwe are captured by the specified model. To check the robustness of the model and the reliability of the results, a battery of diagnostic tests are performed against serial correlation, heteroscedasticity, functional form and normality, and these results are reported in Table 4.

The results on the model diagnostics, shown in Table 4, reveal that the model passed all the tests. Following the stability tests that are performed based on the Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUMQ), with results reported in Figure 2, the parameters in this model are found to be stable over the sample period at the 5% level of significance.

Conclusion

In this study, the impact of renewable energy use on economic growth in Zimbabwe has been empirically examined. The study was motivated by the study country's active involvement in the reduction of global greenhouse gas emission and the positive strides it has made domesti-

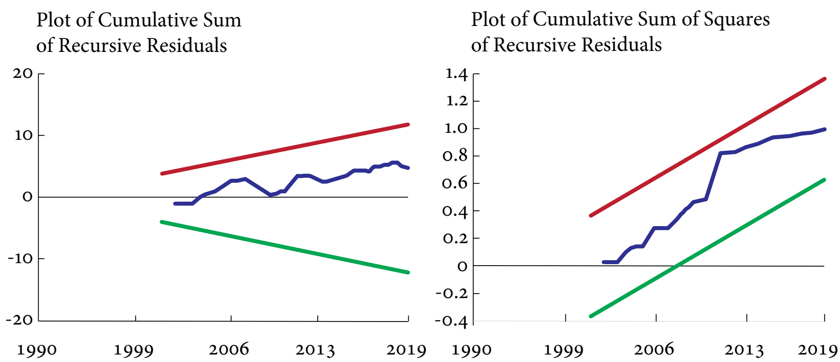

FIGURE 2 CUSUM and CUSUMQ
SOURCE World Bank Group (N. d.)

cally to keep its end of the pledges to the global engines propelling the gas emission reduction agenda – such as the United Nations Framework Convention on Climate Change (UNFCCC) and the various Conferences of the Parties (COP), including the famous COP 17 – on the one hand, and the need to find out if, in the process, the country can turn its fortunes around through the increased consumption of renewable energy, on the other hand. The unavailability of studies on the renewable energy consumption and economic growth link on Zimbabwe necessitated this study. For a country with a depressed economy, authorities in Zimbabwe stand to gain from the policy direction illuminated by the outcome of this study – enhancing evidenced-based policy formulation and implementation in the study country.

Using yearly data stretching from 1990 to 2019, and the relatively newly developed ARDL bounds testing methodology, the findings of the study have shown that in Zimbabwe, the consumption of renewable energy has a positive influence on economic growth, both in the long and short run. Thus, an uptake in the usage of renewable energy increases economic growth in the study country. These results imply that Zimbabwe can kill two birds with one stone. While increasing renewable energy in its energy mix to combat the negative impact of climate change and greenhouse gas emissions, it can also increase its economic growth, thereby reviving the economy that has been on its knees for some time.

Grounded on these results, policy makers in Zimbabwe are recommended to rally behind increased renewable energy, as the consumption of this type of energy has positive ramifications on the economy across all the time horizons.

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