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RENEWABLE ENERGY AND ECONOMIC GROWTH IN ZIMBABWE: A CAUSAL PERSPECTIVE

ABSTRACT

The Granger-causality between renewable energy consumption and economic growth in Zimbabwe is empirically examined using the 1990-2019 time-series data. The study is motivated by the lack of empirical evidence on which variable drives the other in Zimbabwe – between renewable energy consumption and economic growth; and by the need to provide informed guidance to policy makers on whether the country's drive towards cleaner sources of energy in combating global warming have spill over causal effects on economic growth. In an effort to address omitted-variable bias, the study used the autoregressive distributed lag bounds testing approach within a multivariate Granger-causality model. The results of the study confirm the presence of a Granger-causal relationship between renewable energy consumption and economic growth in Zimbabwe. However, this relationship is found to be time variant. While the results reveal the presence of bidirectional Granger-causality between renewable energy consumption and economic growth in the short run, in the long run, unidirectional Granger-causality from renewable energy consumption to economic growth is confirmed. These results establish that in Zimbabwe, energy conservation policies are detrimental to the national economic growth efforts. Policy makers are, therefore, recommended to draft pro-renewable energy policies as the outcome of such is not only reduced carbon footprint but also real sector stimulation.

Keywords: Renewable Energy; Renewable Energy Consumption; Economic Growth; Granger-Causality; Zimbabwe
JEL Classification: Q40; Q20; O40

RIASSUNTO

Energie rinnovabili e crescita economica in Zimbabwe: una prospettiva causale

In questo articolo viene esaminata empiricamente la causalità tra energie rinnovabili e crescita economica in Zimbabwe utilizzando il test di Granger relativamente al periodo 1990-2019. Lo

studio è motivato dalla mancanza di evidenze empiriche circa la relazione tra queste due variabili in Zimbabwe e dalla necessità di capire se guidare il paese verso fonti più pulite di energia per combattere il riscaldamento globale può avere effetti causali di spill-over sulla crescita. Nel tentativo di ottemperare al problema delle variabili omesse, questo studio ha utilizzato il test autoregressivo ad intervalli distribuiti all'interno di un modello di Granger-causalità multivariato.
I risultati confermano la presenza di una relazione di Granger-causalità tra energie rinnovabili e crescita economica in Zimbabwe. Tuttavia, questa relazione sembra essere variabile nel tempo: i risultati rivelano la presenza di Granger-causalità bidirezionale tra queste due variabili nel breve periodo, mentre nel lungo periodo la Granger-causalità risulta essere unidirezionale. Si raccomanda pertanto ai governi di progettare politiche che sviluppano le energie rinnovabili, in quanto in questo modo non si ottiene soltanto una riduzione delle immissioni di carbonio ma anche una stimolazione della crescita economica.

1. Introduction

Renewable energy consumption has taken a centre stage worldwide as global debates on global warming and greenhouse gas emission reduction become the focus of most countries. In an effort to combat the negative effects of global warming, most economies are now resorting to the use of cleaner sources of energy. Empirical literature is beginning to build up on the renewable energy use and economic growth nexus, as development economists and politicians continue to explore the drivers of economic growth (see Jia *et al.,* 2023; Hlongwane and Daw, 2022; Majeed *et al.*, 2021; Charfeddine and Kahia, 2019).

A decent, though increasing number of empirical studies have put the renewable energy consumption and economic growth nexus to the test, examining the impact of the former on the latter. Although the results have been far from being conclusive (see Majeed *et al.*, 2021; Charfeddine and Kahia, 2019; Venkatraja, 2020; Smolović *et al.*, 2020), knowledge has been created in understanding the dynamics of renewable energy consumption and economic growth. However, the causality between renewable energy consumption and economic growth is an area little explored (Runganga and Mishi, 2020; Khobai and Le Roux, 2018; Fotourehchi, 2017), although it is now well known that the impact and the causality relationships between variables are not synonymous, and it is critical to have knowledge of each of the two relationships (see

Odhiambo and Nyasha, 2020). Despite the importance of knowing with certainty the direction of causality between renewable energy consumption and economic growth in order to appropriately direct relevant policy, to the best of our knowledge, no study has been undertaken on the causality between the two variables in Zimbabwe. This could be the first of its own kind. The closest there is, is a study by Runganga and Mishi (2020) that examined the causality between electric power consumption, energy consumption and economic growth for Zimbabwe, using data from 1970-2014. However, this study did not distinguish renewable energy, thereby leaving the renewable energy and economic growth causal nexus gap open.

Against this background, the study empirically examines the Granger-causality between renewable energy consumption and economic growth in Zimbabwe during the period 1990-2019. The outcome of this study will be pivotal in the energy space in general and in Zimbabwe, in particular, as policy makers are equipped with the knowledge of which variable drives the other. Zimbabwe makes an interesting case because it is one of the countries fighting global warming visibly and has transformed its energy space significantly over the past years – increasing the proportion of renewable energy in its energy mix. The climate change shifts and challenges leading to increasing incidences of droughts and cyclone-induced floods (United Nations Climate Change, 2021) left Zimbabwe with no choice but to be active in the renewable energy space. The country has also pledged to reduce greenhouse gas, partly from its efforts of targeting 2 000 megawatts production of energy from renewable sources by 2030 (All Africa, 2022). This is expected to propel the renewable energy market in Zimbabwe, in both the short and long term.

Zimbabwe is one of the fastest-growing energy markets in Africa (Mordor Intelligence, 2022). Energy supply mix in Zimbabwe consists of hydropower (68.17%) coal and other renewable energy sources (31.83%) [Zimbabwe Energy Regulatory Authority (ZERA), 2022]. Independent power producers (IPPs) are playing a significant role in advancing the renewable energy consumption agenda through the creation of incentives from supply to distribution in both urban and rural parts of the country (Lexology, 2022). In response to various policies, renewable energy consumption in Zimbabwe has been trending upwards, from 63.7% in 1990 to 81.5% in 2019 (World Bank, 2022). However, despite notable national progress, challenges still remain in the country’s renewable energy space, with key ones being high production costs affecting the economic viability of renewable energy projects; delays in the execution of renewable energy projects arising from competing priorities on the marked land; and policy inconsistencies on licensing and regulating energy related projects (ZERA, 2022; and Lexology, 2022).

It can be noted that positive strides in the renewable energy space have not been matched in the economic growth front. The gross domestic product (GDP) growth rate has been on a downward spiral since 2011, and was exacerbated by the effects of the Coronavirus in the early 2020s. Although economic growth significantly recovered in 2021 – increasing by 8.5% (World Bank, 2022), attributable to the base-effect-enabled economic recovery from the sharp plunges in economic growth during the Covid-19 period – it is projected slow to 3.4% in 2022 (World Bank, 2022).

The rest of the study is organised as follows: Section 2 reviews empirical literature on the causality between renewable energy consumption and economic growth. Section 3 covers the methodology of the study while Section 4 presents and analyses the results of the study. Section 5 concludes the study.

2. Literature review

A review of renewable energy consumption and economic growth literature reveals that studies on the causality between the two variables are not only scant but also inconclusive. Four possible outcomes are noted in the literature. The outcomes are split among those that support energy-dependent growth; those that support the growth-led renewable energy consumption; those that view renewable energy consumption and economic growth to be mutually causal; and those that uphold the neutrality view, emphasising that renewable energy consumption and economic growth are not causally related.

The first strand of literature, emphasising on energy-driven economic growth, is supported by Runganga and Mishi (2020), Khobai and Le Roux (2018) and Fotourehchi (2017), among others. Runganga and Mishi (2020) examined the causality between electric power consumption and energy consumption and economic growth for Zimbabwe, using data from 1970-2014. The study found a unidirectional casual flow from electric power consumption to economic growth in the long run. In the same vein, Khobai and Le Roux (2018) investigated the causal relationship between renewable energy consumption and economic growth for South Africa using quarterly data from 1990-2014. Using autoregressive distributed lag (ARDL) and vector error correction model, the study found a unidirectional causal flow from renewable energy to economic growth.

Fotourehchi (2017) examined the long-run causality between renewable energy and economic growth from 42 developing countries using data from 1990-2012. Employing Canning and Pedro (2008) long-run causality test, the study found unidirectional causal flow from renewable energy to real gross domestic product. Apergis and Danuletiu (2014) investigated the causal relationship between renewable energy consumption and economic growth for 80 countries using annual data from 1990-2012. Employing the Canning and Pedro (2008) long-run causality test, a long-run causality from renewable energy to economic growth was confirmed in the study.

In the same spirit, Zrelli (2017) analysed the causal relationship between renewable energy and economic growth for 14 Mediterranean countries using data from 1980-2011. Using panel vector error correction model, the study found a unidirectional causal flow from renewable energy to economic growth in the long run.

Besides the studies reviewed above, supporting unidirectional Granger-causality from renewable energy consumption to economic growth, some other studies have also been found lending support to the unidirectional causality running in the opposite direction, i.e., from economic growth to renewable energy consumption. Such studies include Eyuboglu and Uzar (2022), Saad and Taleb (2018) and Matei (2017), among others. Eyuboglu and Uzar (2022) examined the causal relationship between renewable energy consumption and economic growth for some emerging countries using data 1990 to 2015. Using bootstrap panel causality test, the study found unidirectional causality from economic growth to renewable energy for South Africa, Turkey and Thailand.

Saad and Taleb (2018) also studied the causal relationship between renewable energy consumption and economic growth for 12 European Union countries using data from 1990-2014. Employing vector error correction model, the study found a unidirectional causal flow from economic growth to renewable energy consumption in the short run. Khobai and Le Roux (2018) investigated the causal relationship between renewable energy consumption and economic growth for South Africa using quarterly data from 1990-2014. Using autoregressive distributed lag (ARDL) and vector error correction model, their short-run results confirmed a unidirectional causal flow from economic growth to renewable energy consumption. Matei

(2017) also studied the relationship between renewable energy and economic growth for 34 OECD countries for the period 1990-2014. The study found the conservation hypothesis to be valid, where Granger-causality ran from economic growth to renewable energy consumption but only in the short run.

Then, there is a third strand, housing studies that support bidirectional causality between renewable energy consumption and economic growth, emphasising that the two are mutually causal (see Saad and Taleb, 2018; Marinas *et al.*, 2018, among others). Saad and Taleb (2018), in their study on the causal relationship between renewable energy consumption and economic growth for 12 European Union (EU) countries using data from 1990-2014, employing vector error correction model, found bidirectional causal flow between renewable energy consumption and economic growth in the long run.

Marinas *et al.* (2018), in their study on the causal relationship between renewable energy and economic growth for ten EU member states using the ARDL approach, validated bidirectional causality between renewable energy consumption and economic growth in the long run for both the whole group of analysed countries and in the case of seven EU member states studied individually. The same results were affirmed by Matei (2017), in a 34 OECD country study on the relationship between renewable energy and economic growth for the period 1990-2014. The study found the feedback hypothesis to hold but only in the long run.

Zrelli (2017) also validated the presence of bidirectional granger-causality renewable energy consumption and economic growth in a study that aimed at examining the causal relationship between renewable energy and economic growth for 14 Mediterranean countries using data from 1980-2011 and the panel vector error correction model. However, the validation was only on the short run.

Other than the three strands of empirical evidence reviewed, there is the fourth strand that views renewable energy consumption and economic growth as independent or neutral, attesting that the two variables do not Granger-cause one another. However, the empirical literature in support of this fourth strand is thin. Among such literature is Marinas *et al.* (2018), who analysed the causal relationship between renewable energy and economic growth for ten EU member states using data from 1990-2014 and the ARDL methodology. Their study found no Granger-causality between renewable energy consumption and economic growth, but only for two out of the 10 countries – Romania and Bulgaria.

The review of empirical literature on the causality between renewable energy consumption and economic growth has revealed that all possibilities are empirically backed, indicating that the causality between the two variables is not clear-cut. It has been found to vary depending on timeframe of analysis, methodology utilised and study country or region. However, overwhelming empirical evidence is on the unidirectional Granger-causality from renewable energy consumption to economic growth.

3. METHODOLOGY

3.1 The Approach

To empirically examine the causality between renewable energy consumption and economic growth in Zimbabwe, the study employs the autoregressive distributed lag (ARDL) bounds approach, following Pesaran and Shin (1999) and Pesaran *et al.* (2001). The method has been gaining traction over the years as a better approach than the conventional approaches by Engle and Granger's (1987) and Johansen and Juselius' (1990) due to its numerous advantages: the ARDL approach factors in the dynamism among the variables automatically addresses the endogeneity problem; it is flexible yet with robust outcomes; it does not impose the restrictive assumption that all variables must be integrated of the same order; it is executed in a simplified fashion, with only a single-reduced form equation, unlike the conventional methods that utilise a system of equations; and to top it all, it has small sample properties (Pesaran and Shin, 1999; Duasa, 2007; Nyasha and Odhiambo, 2015; Nyasha and Odhiambo, 2019; Nyasha and Odhiambo, 2020, Nyasha *et al.*, 2022; Nyasha and Odhiambo 2022).

To address the omission-of-variable bias associated with bivariate causality models (Odhiambo, 2009; Pradhan, 2011; Nyasha and Odhiambo 2018; Nyasha and Odhiambo, 2022), this study engages a multivariate Granger-causality model to empirically investigate the dynamic causal linkage between renewable energy consumption and economic growth in Zimbabwe. This multivariate Granger-causality model – which accommodates the possibility of the dynamics involving other variables other than renewable energy use and economic growth – is based on the error-correction framework.

3.2 Model Specification

The annual growth rate of real GDP is used in this study as a measure of economic growth (y). The measure is preferred to other measures of economic growth in literature owing to its stability (see, among others, Shan and Ji, 2006; Majid, 2008; Nyasha and Odhiambo 2015, 2021, 2022; Asongu and Diop, 2022; Qabhobho *et al.*, 2023). In the same breadth, renewable energy consumption (Renew) is scientifically measured by the total renewable energy consumed as a percentage of the total energy consumed (Asongu and Odhiambo, 2021; Nyasha and Odhiambo, 2022). The indicator shows the extent of renewable energy use within the country's total energy mix.

To address the omission-of-variable problem, three intermittent variables are incorporated into the model to create a multivariate Granger-causality model. These intermittent variables are domestic investment (Domin), proxied by gross fixed capital formation as a share of GDP; trade openness (Trade), measured by the sum of imports and exports as a percentage of GDP; and labour force (Labour), proxied by the total labour force participation as a percentage of total population aged 15 years and above. The choice of these variables as intermittent variables in the causality model was guided by both theoretical and empirical literature underpinnings, as they have links to economic growth and renewable energy (Abu-Bader and Abu-Qarn, 2008; Zeshan and Ahmad, 2013; Asongu, 2014; Nyasha and Odhiambo, 2015; Ang and McKibbin, 2007; Nyasha and Odhiambo, 2017; Saad and Taleb, 2018).

The study utilised annual time series data from 1990 to 2019, obtained from the World Bank DataBank, Economic Indicators Database (World Bank, 2022).

Following Pesaran *et al.* (2001) and Nyasha and Odhiambo (2022), the cointegration model for this study is expressed in the form of a set of five equations/functions as follows:

$$\Delta y_t = \pi_0 + \sum_{i=1}^{n} \pi_{1i} \Delta y_{t-i} + \sum_{i=0}^{n} \pi_{2i} \Delta Renew_{t-i} + \sum_{i=0}^{n} \pi_{3i} \Delta Domin_{t-i} + \sum_{i=0}^{n} \pi_{4i} \Delta Trade_{t-i} + \sum_{i=0}^{n} \pi_{5i} \Delta Labour_{t-i} + \pi_6 y_{t-1} + \pi_7 Renew_{t-1} + \pi_8 Domin_{t-1} + \pi_9 Trade_{t-1} + \pi_{10} Labour_{t-1} + \mu_{1t} \quad (1)$$

$$\Delta Renew_t = \vartheta_0 + \sum_{i=0}^{n} \vartheta_{1i}\Delta y_{t-i} + \sum_{i=1}^{n} \vartheta_{2i}\Delta Renew_{t-i} + \sum_{i=0}^{n} \vartheta_{3i}\Delta Domin_{t-i} + \sum_{i=0}^{n} \vartheta_{4i}\Delta Trade_{t-i} + \sum_{i=0}^{n} \vartheta_{5i}\Delta Labour_{t-i} + \vartheta_6 y_{t-1} + \vartheta_7 Renew_{t-1} + \vartheta_8 Domin_{t-1} + \vartheta_9 Trade_{t-1} + \vartheta_{10} Labour_{t-1} + \mu_{2t} \quad (2)$$

$$\Delta Domin_t = \Omega_0 + \sum_{i=0}^{n} \Omega_{1i}\Delta y_{t-i} + \sum_{i=0}^{n} \Omega_{2i}\Delta Renew_{t-i} + \sum_{i=1}^{n} \Omega_{3i}\Delta Domin_{t-i} + \sum_{i=0}^{n} \Omega_{4i}\Delta Trade_{t-i} + \sum_{i=0}^{n} \Omega_{5i}\Delta Labour_{t-i} + \Omega_6 y_{t-1} + \Omega_7 Renew_{t-1} + \Omega_8 Domin_{t-1} + \Omega_9 Trade_{t-1} + \Omega_{10} Labour_{t-1} + \mu_{3t} \quad (3)$$

$$\Delta Trade_t = \Phi_0 + \sum_{i=0}^{n} \Phi_{1i}\Delta y_{t-i} + \sum_{i=0}^{n} \Phi_{2i}\Delta Renew_{t-i} + \sum_{i=0}^{n} \Phi_{3i}\Delta Domin_{t-i} + \sum_{i=1}^{n} \Phi_{4i}\Delta Trade_{t-i} + \sum_{i=0}^{n} \Phi_{5i}\Delta Labour_{t-i} + \Phi_6 y_{t-1} + \Phi_7 Renew_{t-1} + \Phi_8 Domin_{t-1} + \Phi Trade_{t-1} + \Phi_{10} Labour_{t-1} + \mu_{4t} \quad (4)$$

$$\Delta Labour_t = \theta_0 + \sum_{i=0}^{n} \theta_{1i}\Delta y_{t-i} + \sum_{i=0}^{n} \theta_{2i}\Delta Renew_{t-i} + \sum_{i=0}^{n} \theta_{3i}\Delta Domin_{t-i} + \sum_{i=0}^{n} \theta_{4i}\Delta Trade_{t-i} + \sum_{i=1}^{n} \theta_{5i}\Delta Labour_{t-i} + \theta_6 y_{t-1} + \theta_7 Renew_{t-1} + \theta_8 Domin_{t-1} + \theta_9 Trade_{t-1} + \theta_{10} \mathrm{Labour}_{t-1} + \mu_{5t} \quad (5)$$

Where:

y = is economic growth, proxied by annual growth rate of real GDP;

Renew = renewable energy consumption, proxied by the proportion of renewable energy consumption in the total energy consumption;

Domin = domestic investment, proxied by the share of gross fixed capital formation in GDP;

Trade = trade openness, proxied by the sum of imports and exports expressed as a percentage of GDP;

Labour = labour force, proxied by total labour force participation as a percentage of the total population, at least 15 years of age;

π_0, ϑ_0, Ω_0, Φ_0 , and θ_0 = respective constants;

$\pi_1 - \pi_5$, $\vartheta_1 - \vartheta_5$, $\Omega_1 - \Omega_5$, $\Phi_1 - \Phi_5$, , and $\theta_1 - \theta_5$ = respective short-run coefficients;

$\pi_6 - \pi_{10}$, $\vartheta_6 - \vartheta_{10}$, $\Omega_6 - \Omega_{10}$, $\Phi_6 - \Phi_{10}$, and $\theta_6 - \theta_{10}$ = respective long-run coefficients;

Δ = difference operator;

n = lag length;

t = time period; and

μ_{it} = white-noise error terms.

The ECM-based Granger-causality model associated with the specified cointegration model is presented as:

$$\Delta y_t = \pi_0 + \sum_{i=1}^{n} \pi_{1i} \Delta y_{t-i} + \sum_{i=1}^{n} \pi_{2i} \Delta Renew_{t-i} + \sum_{i=1}^{n} \pi_{3i} \Delta Domin_{t-i} + \sum_{i=1}^{n} \pi_{4i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \pi_{5i} \Delta Labour_{t-i} + \pi_{11} ECM_{t-1} + \mu_{1t} \quad (6)$$

$$\Delta Renew_t = \vartheta_0 + \sum_{i=1}^{n} \vartheta_{1i} \Delta y_{t-i} + \sum_{i=1}^{n} \vartheta_{2i} \Delta Renew_{t-i} + \sum_{i=1}^{n} \vartheta_{3i} \Delta Domin_{t-i} + \sum_{i=1}^{n} \vartheta_{4i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \vartheta_{5i} \Delta Labour_{t-i} + \vartheta_{11} ECM_{t-1} + \mu_{2t} \quad (7)$$

$$\Delta Domin_t = \Omega_0 + \sum_{i=1}^{n} \Omega_{1i} \Delta y_{t-i} + \sum_{i=1}^{n} \Omega_{2i} \Delta Renew_{t-i} + \sum_{i=1}^{n} \Omega_{3i} \Delta Domin_{t-i} + \sum_{i=1}^{n} \Omega_{4i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \Omega_{5i} \Delta Labour_{t-i} + \Omega_{11} ECM_{t-1} + \mu_{3t} \quad (8)$$

$$\Delta Trade_t = \Phi_0 + \sum_{i=1}^{n} \Phi_{1i} \Delta y_{t-i} + \sum_{i=1}^{n} \Phi_{2i} \Delta Renew_{t-i} + \sum_{i=1}^{n} \Phi_{3i} \Delta Domin_{t-i} + \sum_{i=1}^{n} \Phi_{4i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \Phi_{5i} \Delta Labour_{t-i} + \Phi_{11} ECM_{t-1} + \mu_{4t} \quad (9)$$

$$\Delta Labour_t = \theta_0 + \sum_{i=1}^{n} \theta_{1i} \Delta y_{t-i} + \sum_{i=1}^{n} \theta_{2i} \Delta Renew_{t-i} + \sum_{i=1}^{n} \theta_{3i} \Delta Domin_{t-i} + \sum_{i=1}^{n} \theta_{4i} \Delta Trade_{t-i} + \sum_{i=1}^{n} \theta_{5i} \Delta Labour_{t-i} + \theta_{11} ECM_{t-1} + \mu_{5t} \quad (10)$$

Where:

ECM = error-correction term;

π_{11}, ϑ_{11}, Ω_{11}, Φ_{11} and θ_{11} = respective coefficients for the error-correction terms;

μ_{it} = mutually uncorrelated white-noise residuals; and

All other variables and characters are as defined in Equations 1-5.

3.3 Pre-estimation Tests

Before the analysis of the Granger-causality between variables is carried out, the data is first subjected to unit root tests. Although the ARDL-bounds testing approach adopted for this study does not impose that the unit root tests be done before the analysis is conducted, these tests assist in determining if the series are integrated of order one or less, as the chosen approach would be inappropriate should some or all of the variables be integrated of order two [I(2)]. To this end, the study employs two tests for unit root – the Dickey-Fuller Generalised Least Squares (DF-GLS) and the Perron (1997) unit root tests. While the former has more power in the presence of an unknown trend or mean compared to the Augmented Dickey-Fuller test (Elliott *et al.*, 1996), the latter is recommended in the event that the data analysed has structural breaks (Perron, 1997).

The stationarity tests are followed by cointegration tests, based on the ARDL bounds approach, as causality tests can only be carried out if there is at least one cointegration vector in the model.

4. Data analysis and empirical results

4.1 Unit Root

The Dickey-Fuller generalised least squares (DF-GLS) and Perron (1997) tests for stationarity are used to determine the level of integration of the variables. The former is more reliable than the Dickey-Fuller and the Augmented Dickey-Fuller unit root tests (Elliott *et al.*, 1996) while the latter caters for structural breaks in data (Perron, 1997; Nyasha and Odhiambo 2017). The results of the unit root tests are presented in Table A.

As summarised in Table A, the variables used in the study are stationary either in levels or after differenced once – thereby confirming the applicability of the ARDL based methodology for data analysis.

TABLE A - *Results of Unit Root Tests*

	Dickey-Fuller Generalised Least Square (DF-GLS)		Perron (1997)	
Variable	**Without Trend**		**Without Trend**	
	Variables in Levels	Variables in Levels	Variables in Levels (Break Year)	First Difference (Break Year)
y	-3.185***	-	-5.883*** (2008)	-
Renew	-0.636	-4.951***	-4.049 (2001)	-5.920*** (1999)
Domin	-2.111**	-	-4.755 (1998)	-8.454*** (1999)
Trade	-2.340**	-	-4.940* (2012)	-
Labour	-1.746*	-	-12.807*** (2011)	-

Note: ***, ** and * denote stationarity at 1%, 5% and 10% significance level.

4.2 Cointegration

The ARDL bounds testing approach was employed to examine if there exists a long-run relationship between the variables in the specified model. The null hypothesis that the variables are not cointegrated is tested against the alternative hypothesis that the variables are cointegrated. To determine whether the null hypothesis is rejected, the calculated F-statistic should be higher than Pesaran *et al.*'s (2001) upper bound critical value at the corresponding significance level. If it is less than Pesaran *et al.*'s (2001) lower bound critical value, the null hypothesis is accepted. The cointegration test is carried out in all the functions of the model following the same procedure; and the results are presented in Table B.

As reflected in Table B, cointegration is confirmed in two of the four functions – the economic growth (y) and the labour force (Labour) functions. Since the existence of a long-run equilibrium relationship between variables is only a suggestion that Granger-causality exists in at least one direction, and does not reveal the direction of causal flow between the variables, the cointegration outcome allows the study to proceed with the examination of the direction of causality between variables in the model.

TABLE B - *Results of the Bounds F-test for Cointegration*

<table>
<tr><th>Dependent variable</th><th colspan="2">Function</th><th colspan="2">F-statistic</th><th colspan="2">Cointegration status</th></tr>
<tr><td>y</td><td colspan="2">F(y|Renew, Domin, Trade, Labour)</td><td colspan="2">4.41**</td><td colspan="2">Cointegrated</td></tr>
<tr><td>Renew</td><td colspan="2">F(Renew|y, Domin, Trade, Labour)</td><td colspan="2">1.11</td><td colspan="2">Not cointegrated</td></tr>
<tr><td>Domin</td><td colspan="2">F(Domin|y, Renew, Trade, Labour)</td><td colspan="2">1.15</td><td colspan="2">Not cointegrated</td></tr>
<tr><td>Trade</td><td colspan="2">F(Trade|y, Renew, Domin, Labour)</td><td colspan="2">2.87</td><td colspan="2">Not cointegrated</td></tr>
<tr><td>Labour</td><td colspan="2">F(Labour|y, Renew, Domin, Trade)</td><td colspan="2">4.68**</td><td colspan="2">Cointegrated</td></tr>
<tr><td colspan="7">Asymptotic critical values</td></tr>
<tr><td rowspan="3">Pesaran et al. (2001), p.300 Table CI(iii) Case III</td><td colspan="2">1%</td><td colspan="2">5%</td><td colspan="2">10%</td></tr>
<tr><td>I(0)</td><td>I(1)</td><td>I(0)</td><td>I(1)</td><td>I(0)</td><td>I(1)</td></tr>
<tr><td>3.74</td><td>5.06</td><td>2.86</td><td>4.01</td><td>2.45</td><td>3.52</td></tr>
</table>

Note **: denotes statistical significance at 5% level.

Although the error-correction term is included in all the functions of the causality model (Equations 6-10), it is only included in the causality estimation in the functions with cointegration vectors (Equations 6 and 10) (see Nyasha *et al.*, 2017; 2018, among others).

The short-run causality is confirmed by the F-statistics of the Wald Test or the Variable Deletion Test on the explanatory variables. However, the long-run causality is determined by the sign and significance of the coefficient of the error-correction term.

4.3 Granger-Causality

Following the establishment of cointegration in two of the functions, the study proceeds with the examination of the casualty between variables in the specified model, using the ARDL procedure. The results of the Granger-causality test are summarised in Table C.

TABLE C - *Results of the Granger-Causality Test*

Dependent variable	F-statistics [probability]					ECT_{t-1} [t-statistics]
	Δy_t	$\Delta Renew_t$	$\Delta Domin_t$	$\Delta Trade_t$	$\Delta Labour_t$	
Δy_t	-	3.546* [0.074]	11.122*** [0.003]	1.005 [0.328]	0.037 [0.849]	-0.911*** [-4.624]
$\Delta Renew_t$	6.927** [0.015]	-	0.419 [0.524]	8.095*** [0.009]	2.166 [0.155]	-
$\Delta Domin_t$	0.116 [0.737]	4.007* [0.062]	-	1.577 [0.222]	0.614 [0.442]	-
$\Delta Trade_t$	3.981* [0.060]	0.201 [0.659]	0.745 [0.398]	-	3.122* [0.093]	-
$\Delta Labour_t$	4.000* [0.060]	0.045 [0.835]	0.138 [0.991]	4.439** [0.049]	-	-0.173*** [-2.898]

Note: ***, ** and * denote stationarity at 1%, 5% and 10% significance level.

As reported in Table C, the empirical results of the Granger-causality tests reveal that in Zimbabwe, as expected, there is a causal relationship between renewable energy consumption and economic growth. While there is bidirectional Granger-causality between renewable energy consumption and economic growth in the short run, in the long run, it is renewable energy consumption that drives economic growth. These results show that increasing the level of renewable energy consumption is good for the economic growth process in the study country – which has a mutual beneficial effect on the renewable energy consumed, in the immediate term. However, in the long term, investment in renewable energy pays off as the economy responds positively to increase in renewable energy consumption. These results, therefore, reveal that efforts by Zimbabwe to go green and use clean energy do not only assist in cleaning its environment and contribute towards the reduction of global carbon footprint, but it also assists in reviving its economy.

Results reported in Table C further reveal that besides economic growth, domestic investment also benefits from renewable energy consumption as the study established a unidirectional Granger-causal flow from renewable energy consumption to domestic investment in both the short and long run. However, renewable energy consumption has been shown to benefit from trade openness. This is confirmed by the latter that is found to Granger-cause the former, but only in the short run.

Other results of the study show that in Zimbabwe, there is: short-run and long-run unidirectional causality from domestic investment to economic growth and from economic growth to labour force; short-run unidirectional causality from economic growth to trade openness; short-run bidirectional causality between trade openness and labour force; long-run causality from trade openness to labour force; and no causality between renewable energy consumption and labour force, trade openness and domestic investment as well as between labour force and domestic investment.

5. CONCLUSION

This study has empirically examined the Granger-causality between renewable energy consumption and economic growth in Zimbabwe using time-series data from 1990 to 2019. The study was motivated by the need to provide informed guidance to policy makers on whether the country's drive towards cleaner sources of energy in combating global warming have spill over causal effects on economic growth, on the one hand, and the lack of empirical evidence on which variable drives the other – between renewable energy consumption and economic growth – in Zimbabwe, on the other hand. Filling of this gap had key policy implications, relevant in guiding energy and growth policy in the study country. To achieve this objective, the study used the ARDL bounds testing procedure. In order to address omission-of-variable bias, the study introduced three intermittent variables – namely, domestic investment, trade openness and labour force – in addition to renewable energy consumption and economic growth – thereby forming a multivariate Granger-causality model. The results of the study revealed that in Zimbabwe, there is bidirectional Granger-causality between renewable energy consumption and economic growth in the short run. However, in the long run, there is unidirectional Granger-causality from renewable energy consumption to economic growth. These results imply that in Zimbabwe, energy conservation policies are detrimental to the national economic growth efforts. Policy makers are recommended to draft pro-renewable energy policies as the outcome of such is reduced carbon footprint and stimulated economic growth. Future research on the subject would benefit from a detailed review of empirical literature by methodology and study country groups and examine whether these facets affect the causality outcome.

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