Renewable electricity consumption and economic growth: A comparative study of South Africa and Zimbabwe

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Renewable electricity consumption and economic growth: A comparative study of South Africa and Zimbabwe

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Abstract: The study conducts a comparative analysis of the relationship between renewable electricity consumption and economic growth in South Africa and Zimbabwe. The study utilises time series data spanning from 1990 to 2019 collected from the World Bank and International Energy Agency (IEA). The study performed the Dickey-Fuller Generalised Least Squares and Phillips-Perron unit root test, ARDL Bounds test for cointegration and optimal lags models. Empirical results revealed that in the short run renewable electricity consumption has a negative impact on economic growth in both countries. In the long run, however, in South Africa it has a negative statistically significant effect in South Africa and a positive statistically insignificant effect in Zimbabwe on economic growth. The study recommends the revision of renewable electricity policies in both countries to boost economic growth significantly in both countries.

Keywords: Renewable electricity consumption, Economic growth, South Africa, Zimbabwe, ARDL model.

JEL Specification: C32, O13, O43, Q43

1. INTRODUCTION

Renewable energy consumption is one of the main objectives of many countries in the world today trying to reduce CO2 emissions that damage the environment. Electricity is the backbone of an economy as it is needed in almost all the sectors of the economy today. South Africa and

Zimbabwe has a vast option of generating renewable energy from solar, wind, water, tidal, geothermal and biofuels. The adoption of these renewable sources can help reduce the problem of loadshedding in South Africa and blackouts taking longer hours in Zimbabwe.

SADC has several legal and policy instruments to guide the development of renewable energies in the region. These includes: SADC Energy Protocol (1996), Revised RISDP (2015-2020), SADC Industrialization strategy and Roadmap (2015), Regional Infrastructure Development Master Plan: Energy Sector Plan (2012), Regional Energy Access Strategy and Action Plan, and AU Agenda 2063 (SADC, 2019). Other institutions established in SADC to regulate the renewable energy subsector as well as implement various renewable energy programs, projects and activities are the Regional Electricity Regulators Association of Southern Africa (RERA), and the Southern African Power Pool (SAPP). To complement the major regulating institutions, most SADC Member States continue to adopt renewable policies and strategies.

The studies that focused on energy consumption and economic growth in South Africa and Zimbabwe were done by Khobai and Le Roux (2017), Stungwa *et al.* (2022), Hlongwane and Daw (2021a), Ouedraogo (2017), Shahbaz *et al.* (2017), (Bekun *et al.*, 2019) and Khobai (2018). However, some of the studies did not focus specifically on renewable electricity consumption but they focused on electricity consumption in general. The purpose of this study, however, is to focus on renewable electricity consumption and economic growth in South Africa and Zimbabwe. This is important for government, policymakers, Eskom and ZETDC in South Africa and Zimbabwe to reveal how renewable electricity consumption affects economic growth in these two countries. This comparative study is important for renewable energy policy formulation in both countries.

The reminder of the study is structured as follows: Section 2 provides the literature review on electricity consumption and economic growth. Section 3 provides the data discussion, methodology and model specification utilised in the study. Section 4 provides results and discussion of the study. Section 5 provides the conclusion and policy recommendations of the study while Section 6 provides the references of the sources used in the study.

2. LITERATURE REVIEW

Studies found positive relationship: Athukorala and Wilson (2010) investigate the short run dynamics and long run equilibrium relationship between residential electricity demand and the factors influencing demand, such as capita income, electricity price, kerosene oil price, and liquefied petroleum gas price, using onion data for Sri Lanka from 1960 to 2007. The primary conclusions of the article were that raising the price of power is not the most effective technique for reducing electricity use**.** Mohanty and Chaturvedi (2015) examine the weather electricity energy consumption on economic growth in Indian using the annual data spanning 1970-1971 to 2011-2012. Using granger causality test and Engle-Granger technique, their study suggested that electricity energy consumption has a positive relationship on economic growth in the short run and long run.

Niu *et al.* (2013) analyzed the causality between electricity consumption and human development and assesses the changing trend of electricity consumption. they have started employed panel data from 1990 to 2009 for 50 countries divided into four groups according to the income. For human development indicator, per capita GDP, consumption expenditure, urbanization rate, life expectancy at birth and the adult literacy rate was selected. The result from the study demonstrated long run bidirectional causality existing between electricity consumption and five indicators. The study further suggested, to enhance human development, the electricity should be incorporated into the basic public services construction to improve the availability of electricity for low-income residents.

Ouédraogo (2010) examined the direction of causality between electricity consumption and economic growth in Burkina Faso for the period of 1968 to 2003. The bounce test yields evidence of cointegration between electricity consumption GDP and capital formation when electricity consumption and GDP are used as dependent variables. The start argued that electricity is a significant factor in socio economic development in Burkina Faso, therefore energy policies must be implemented to ensure that electricity generates few potential negative impacts. Bangladesh one of the largest populous countries in the world is being overwhelmed by an access demand of energy from the households, hence, Debnath *et al.* (2015) investigated the bottom up approach towards modelling the aggregate energy demand of right households of Bangladesh from 2010 to 2015. The energy demand pathway model demonstrated a significant rise in energy demand.

Bekhet and bt Othman (2011) investigated the relationship between electricity consumption, consumer price index, gross domestic product, and foreign indirect investment for period of 1971 to 2009. The vector error correction model was employed to estimate the causal relationship between electricity consumption with respective independent variables. The results demonstrated that electricity consumption what is the cointegrated with all their respective independent variables. The results further showed that there long runs causality from electricity consumption to FDI, GDP growth and inflation was found to be significant.

Lionel (2013) investigated the relationship between electricity supply and economic development in Nigeria using an annual time series data from 1970-2009. The paper employed error correction model for empirical analysis of the study. The results showed that per capita GDP, lagged electricity supply, Technology, cut it down at the significant variables that influence economic development in Nigeria. Electricity supply has an influence in economic development in Nigeria, but its impact is very low.

Jamil and Ahmad (2010) investigated the relationship between electricity consumption, electricity prices and economic growth in Pakistan. The study employed annual time series data spanning for the period from 1960 to 2008. The study employed a Vector Error Correction Model (VECM) and Granger causality test to analyse the relationship between the variables in Pakistan. Empirical results revealed short run positive relationship between electricity consumption and economic growth in Pakistan. Granger causality results revealed unidirectional causal relationship from economic growth to electricity consumption that indicates economic growth stimulates electricity consumption in the long run. The researchers recommend that it is essential for Pakistan policymakers to plan and increase infrastructure development to meet increasing electricity demand. The researchers also recommend that government should adopt policies to sustain electricity supply.

Hussain *et al.* (2016) forecasted electricity consumption in Pakistan. The study borrowed available annual time series data spanning for the period from 1980 to 2011. The study employed Holt-Winter and Autoregressive Integrated Moving Average (ARIMA) models to forecast electricity consumption in Pakistan. The empirical results revealed that electricity demand is higher in the household sector than in other sectors and that electricity generation would be lesser than the increase in electricity generation. The researchers recommend that policymakers should focus on short- and long-term projects such as renewable sources of electricity to balance the supply-demand gap in Pakistan.

da Silva *et al.* (2016) investigated electricity supply security and the future role of renewable energy sources in Brazil. The researchers found that hydroelectricity generation is the backbone of electricity supply in Brazil. The recent drought exposed the exposed vulnerability of electricity supply and drew significant immediate attention to address power outages. The researchers highlight that Brazil faces considerable increases in electricity consumption and policy makers should focus on renewable energy sources to balance energy supply and reduce dependence on hydroelectric power.

Osman *et al.* (2016) conducted a study on electricity consumption and economic growth in the GCC countries. The study borrowed available annual panel data spanning from 1975 to 2012. The study employed panel estimation techniques to analyse the relationship between the variables. Empirical results revealed positive results between the variables both in the short and long run period. The researchers recommend that if these countries adopt or implement policies that conserve electricity, this will have negative impact on economic growth of these countries.

Salahuddin and Alam (2016) performed research in OECD nations on information and communication technologies, electricity consumption, and economic development. The study used publicly accessible yearly panel data spanning the years 1985 to 2012. Panel estimation techniques were used in the study to examine the association between the variables. According to empirical findings, electricity usage boosts economic growth. Based on empirical findings, the researchers urge that technologies that encourage efficient power usage be adopted to lessen the risks associated with electricity consumption.

Zhang *et al.* (2017) investigated electricity consumption and economic growth in China. The study utilises available literature spanning from 1978 to 2016 that focuses on electricity generation and economic growth. The study reveals that vector error correction model (VECM) and vector autoregressive (VAR) model are the most employed models in the analysis. The study revealed that there is interaction between electricity consumption and economic growth. The researchers stresses that due to employment of different models, the results are not the same. The researchers recommend that China should increase the renewable sources of electricity to balance the strain on electricity supply and maintain environmentally friendly status.

Ouedraogo (2017) developed a long-term power supply-demand model for Africa. The system-based method proposed by Schwartz in the context of Long-term alternative planning was used in the study. The findings found that, despite increased electrical output, demand for electricity will remain high by 2030 and 2040, signifying an inadequate supply of electricity. The researchers propose that energy efficiency initiatives be introduced to minimize Africa's high energy consumption levels.

Shahbaz *et al.* (2017) conducted a study on the dynamics of electricity consumption, oil price and economic growth on a panel global perspective. The study borrowed available annual panel data for 157 countries spanning from 1960 to 2014. The study employed panel estimation techniques to analyse the relationship between the variables. Empirical results revealed a short run positive relationship of electricity consumption on economic growth. The researchers reveals that more vigorous policies on electricity to be implemented to attain sustainable long run economic growth. The study recommends electricity conversion policies to trigger economic growth.

Belaid and Youssef (2017) investigated the impact of environmental deterioration, renewable and non-renewable power usage on Algerian economic growth. The study used yearly time series data from 1980 to 2012. To examine the link between variables in Algeria, the study used an autoregressive distributed lad model and the Granger causality test. The empirical findings demonstrated that the variables had unidirectional long run causation. According to the report, investing in renewable energy will promote economic development and help Algeria combat unemployment.

Kahouli (2018) investigated the causal relationship between electricity consumption, CO_2 emissions, research and development stocks and economic growth of Mediterranean countries. The study borrowed annual panel data spanning for the period from 1990 to 2016. The study employed panel estimation techniques to analyse the relationship between the variables. The empirical results revealed that electricity consumption boosts economic growth in the Mediterranean countries. The researchers recommend that policymakers should implement policies of electricity that are environmentally friendly.

The relationship between Bangladesh's power use and gross domestic product is examined by Dey and Tareque (2019). The research used publicly accessible time series data from 1971 to 2014. An autoregressive distributed lag model is used in the study to examine the connection between Bangladesh's energy usage and economic expansion. According to empirical findings, both short- and long-term economic growth are positively correlated with power usage. In Bangladesh, the researchers advise implementing efficient policies for power generation and conservation.

Bekun *et al.* (2019) investigated the relationship between energy consumption, carbon emissions and economic growth in South Africa. The study borrowed available annual time series data spanning for the period from 1960 to 2016. The study employed Granger causality test to analyse the relationship between the variables in South Africa. The results revealed a positive relationship between electricity consumption and economic growth in South Africa. The researchers recommend that the electricity conservation policies harm economic growth.

Stungwa *et al.* (2022) investigated the relationship between electricity consumption and economic growth in South Africa for the period from 1971 to 2014. The study utilised borrowed time series data on an ARDL model to reveal short and long run relationships between the variables. The empirical results revealed that statistically significant short run and positive long run relationships between renewable electricity consumption and economic growth in South Africa. The researchers recommend prioritizing renewable energy consumption based on empirical evidence.

Khobai (2018) looked at the relationships between South Africa's economic growth and the generation of renewable power. Quarterly time series data from the first quarter of 1997 to the fourth quarter of 2012 were used in the analysis. Granger causality tests and a vector error correction model were used in the study to examine the relationships between the variables. The empirical findings revealed a one-way causal relationship between the production of electricity and economic growth, and that the production of electricity from renewable energy sources accelerates economic growth. The researchers advise the government of South Africa to make the necessary efforts to choose energy policies that do not adversely affect economic growth.

Studies that found an inverse relationship: In the case of Pakistan from 1991 to 2013, Shahbaz (2015) looked at the effects of energy scarcity on sectoral GDP, including the agricultural, industrial, and service sectors. The empirical analysis of the study made use of the ordinary least squares (OLS). The study's findings indicated an inverse relationship between power deficit and agriculture sector output as well as an inverse relationship between energy scarcity and industrial sector output.

The relationship between Vietnam's economic growth and energy consumption is reviewed by Ha and Ngoc (2021). The research used publicly accessible yearly time series data from 1971 to 2017. To analyse the connection between the variables, the study uses an asymmetric autoregressive distributed lag model. According to the empirical findings, both in the short and long terms, energy consumption has a negative influence on Vietnam's economic growth that is bigger than any favourable effects. According to the experts, the government should promote the use of clever machinery and devices with low electricity requirements, as well as the use of renewable energy sources as an alternative, by businesses and individuals.

3. METHODOLOGY

The study utilises borrowed time series data spanning for the period from 1990 to 2019 sourced from the World Bank to analyse renewable electricity consumption and economic growth a comparative study of South Africa and Zimbabwe utilising renewable electricity consumption, CO2 emissions, capital formation and trade as control variables shown in the growth function below adopted from Khobai and Le Roux (2017).

LGDP = f(LEC, LCO2, LKF, LTR)……………………………………………………..… (3.1)

Table 3.1 Data Sources and Description

Symbol	Variable	Description	Unit	Source
LGDP	Economic growth	Gross domestic product per capita growth	Annual %	World Bank
LLEC	Renewable electricity consumption	Renewable energy consumption is the share of renewable energy in total final energy consumption.	% Of final total energy consumption	World Bank
LCO2	Carbon dioxide emissions	Carbon dioxide emissions from all sources	Metric tonnes	IEA
LKF	Gross capital formation	Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.	% Of GDP	World Bank

		Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress."		
LTR	Trade	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	% Of GDP	World Bank

Source: Authors' own compilation

The empirical model estimation utilised in the study was adopted from the studies of Khobai and Le Roux (2017), Stungwa *et al.* (2022), Hlongwane and Daw (2021a) and Hlongwane and Daw (2021b). The study modifies this model to suit the study's main objective. The linear econometric model can be specified as follows:

$$LGDP_t = \beta_0 + \beta_1 LEC_t + \beta_2 LCO2_t + \beta_3 LKF_t + \beta_4 LTR_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

Whereby,

LGDP = natural logarithm of gross domestic product per capita

LEC = natural logarithm of renewable electricity consumption

LCO2 = logged CO2 emissions

LKF = natural logarithm of capital formation

LTR = natural logarithm of trade

ε_t = is the error term

t = refers to the period

β_{0_4} = refers to the constants

3.2 Unit root

Tests of unit root are estimated at first before estimating Autoregressive Distributed Lags (ARDL) model. This is done to determine the level of integration of variables and avoid problems of spurious regressions if the variables are found to be stationary. The study employs the Dickey-Fuller Generalised Least Squares (DF-GLS) and Phillips-Perron (PP) unit root test proposed by Elliott *et al.* (1992) and Phillips and Perron (1988). Elliott *et al.* (1996) argues that the DF-GLS test has more power in the presence of an unknown trend or mean compared to the ADF and PP unit root test. The null hypothesis of unit root is tested against the alternative hypothesis of stationarity in all tests. If the computed DF-GLS test statistic is greater than the critical values at 1%, 5% and 10% level of significance, the null hypothesis of unit root is rejected and conclude that the series is stationary. This study is used to determine the long-time properties of the variables employed in the model. If a time series is found to be stationary, it means that its variance, mean, and covariance remain constant over time, and that the result of their analysis is reliable and can be used to forecast future economic activities. The study also employs the VAR lags criterion to determine the optimal number of lags to use in the estimation.

3.3 ARDL Model and long run relationships

The study adopts the Autoregressive Distributed Lags model proposed by Pesaran *et al.* (2001) to analyse renewable electricity consumption and economic growth, a comparative study of South Africa and Zimbabwe. Studies that make the literature review shows that majority of the studies has been focusing on a single country analysis and limited studies has carried a comparative analysis on the topic. This study, however, utilises the ARDL model to show the short run and long run relationships between the variables and to reveal if the results found by majority of the studies in the literature section is the same in South Africa and Zimbabwe. The ARDL model for long run relationships can be specified as given in Equations 3.3 to 3.7 below:

$$LGDP_t = \beta_{01} + \sum_{i=1}^{p} k_{11}\, LGDP_{t-i} + \sum_{i=1}^{q} k_{21}\, LEC_{t-i} + \sum_{i=1}^{q} k_{31}\, LCO2_{t-i} + \sum_{i=1}^{q} k_{41}\, LKF_{t-i} + \sum_{i=1}^{q} k_{51}\, LTR_{t-i} + \varepsilon_t \quad (3.3)$$

$$LEC_t = \beta_{02} + \sum_{i=1}^{p} k_{12}\, LEC_{t-i} + \sum_{i=1}^{q} k_{22}\, LGDP_{t-i} + \sum_{i=1}^{q} k_{32}\, LCO2_{t-i} + \sum_{i=1}^{q} k_{42}\, LKF_{t-i} + \sum_{i=1}^{q} k_{52}\, LTR_{t-i} + \varepsilon_t \quad (3.4)$$

$$LCO2_t = \beta_{03} + \sum_{i=1}^{p} k_{13}\, LCO2_{t-i} + \sum_{i=1}^{q} k_{23}\, LEC_{t-i} + \sum_{i=1}^{q} k_{33}\, LGDP_{t-i} + \sum_{i=1}^{q} k_{43}\, LKF_{t-i} + \sum_{i=1}^{q} k_{53}\, LTR_{t-i} + \varepsilon_t \quad (3.5)$$

$$LKF_t = \beta_{04} + \sum_{i=1}^{p} k_{14}\, LKF_{t-i} + \sum_{i=1}^{q} k_{24}\, LCO2_{t-i} + \sum_{i=1}^{q} k_{34}\, LEC_{t-i} + \sum_{i=1}^{q} k_{44}\, LGDP_{t-i} + \sum_{i=1}^{q} k_{54}\, LTR_{t-i} + \varepsilon_t \quad (3.6)$$

$$LTR_t = \beta_{05} + \sum_{i=1}^{p} k_{15}\, LTR_{t-i} + \sum_{i=1}^{q} k_{25}\, LKF_{t-i} + \sum_{i=1}^{q} k_{35}\, LCO2_{t-i} + \sum_{i=1}^{q} k_{45}\, LEC_{t-i} + \sum_{i=1}^{q} k_{55}\, LGDP_{t-i} + \varepsilon_t \quad (3.7)$$

3.4 ARDL-Error Correction Model and short run relationships

After confirmation of long run relationships existing between taxation, economic growth, trade, inflation, and government expenditure using the ARDL-Bounding tests to cointegration, the study employs the ARDL-ECM model to determine the short run relationships between the variables. Short run dynamic error correction model can be derived from the ARDL long run estimations models made through a simple linear transformation. Equations 3.8 to 3.12 below shows the ARDL-ECM model whereby, ECT_{t-1} is an error correction term that should be negative and statistically significant, Δ represents the differenced short run variables while λ shows the coefficient of the speed of adjustment to long run equilibrium:

$$\Delta LTAX_t = \beta_{01} + \sum_{i=1}^{p} \alpha_{11}\, \Delta LTAX_{t-i} + \sum_{i=1}^{q} \alpha_{21}\, \Delta LGDP_{t-i} + \sum_{i=1}^{q} \alpha_{31}\, \Delta LTRA_{t-i} + \sum_{i=1}^{q} \alpha_{41}\, \Delta LINF_{t-i} + \sum_{i=1}^{q} \alpha_{51}\, \Delta LGOV_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (3.8)$$

$$\Delta LGDP_t = \beta_{02} + \sum_{i=1}^{p} \alpha_{12}\, \Delta LGDP_{t-i} + \sum_{i=1}^{q} \alpha_{22}\, \Delta LTAX_{t-i} + \sum_{i=1}^{q} \alpha_{32}\, \Delta LTRA_{t-i} + \sum_{i=1}^{q} \alpha_{42}\, \Delta LINF_{t-i} + \sum_{i=1}^{q} \alpha_{52}\, \Delta LGOV_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (3.9)$$

$$\Delta LTRA_t = \beta_{03} + \sum_{i=1}^{p} \alpha_{13}\, \Delta LTRA_{t-i} + \sum_{i=1}^{q} \alpha_{23}\, \Delta LGDP_{t-i} + \sum_{i=1}^{q} \alpha_{33}\, L\Delta TAX_{t-i} + \sum_{i=1}^{q} \alpha_{43}\, \Delta LINF_{t-i} + \sum_{i=1}^{q} \alpha_{53}\, \Delta LGOV_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (3.10)$$

$$\Delta LINF_t = \beta_{04} + \sum_{i=1}^{p} \alpha_{14}\, \Delta LINF_{t-i} + \sum_{i=1}^{q} \alpha_{24}\, \Delta LTRA_{t-i} + \sum_{i=1}^{q} \alpha_{34}\, \Delta LGDP_{t-i} + \sum_{i=1}^{q} \alpha_{44}\, \Delta LTAX_{t-i} + \sum_{i=1}^{q} \alpha_{54}\, \Delta LGOV_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (3.11)$$

$$\Delta LGOV_t = \beta_{05} + \sum_{i=1}^{p} \alpha_{15}\, \Delta LGOV_{t-i} + \sum_{i=1}^{q} \alpha_{25}\, \Delta LINF_{t-i} + \sum_{i=1}^{q} \alpha_{35}\, \Delta LTRA_{t-i} + \sum_{i=1}^{q} \alpha_{45}\, \Delta LGDP_{t-i} + \sum_{i=1}^{q} \alpha_{55}\, \Delta LTAX_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (3.12)$$

3.5 Diagnostics Tests

3.5.1 Serial Correlation: The study will utilise the Breusch-Godfrey Serial Correlation LM test to determine serial correlation in the model.

3.5.2 Heteroskedasticity: The study will utilise the Breusch-Pagan-Godfrey test to find out if the condition of homoscedasticity is found or not in the estimated model.

3.5.3 Normality test: The study will employ the Jarque-Berra histogram normality test to check if the estimated model's residuals are normally distributed and ascertain no violation of the normality rule of linear models.

3.5.4 Stability tests: The study will rely on the CUSUM SUM, CUSUMSQ and Ramsey RESET tests to ensure the stability of the estimated parameter.

4. RESULTS AND INTEPRETATIONS

Table 4.1: Unit root test South Africa

Variables	**Dickey-Fuller GLS**				**Phillips-Perron**			
	Constant		Trend & Intercept		Constant		Trend & Intercept	
	Level	Δ	Level	Δ	Level	Δ	Level	Δ
LGDP	-2.1460 **	-5.5699 ***	-2.3514	-6.0011 ***	-2.4243	-6.1284 ***	-1.9722	-13.229 ***
LEC	-0.3106	-2.1225 **	-1.5267	-4.2298 ***	-0.6310	-4.3882 ***	-1.9552	-4.2575 **
LCO2	-1.3884	-3.9354 ***	-1.5654	-4.2902 ***	-1.5052	-4.4301 ***	-1.8703	-4.3842 **
LKF	-1.9685 **	-4.8386 ***	-2.1438	-4.8875 ***	-2.1327	-4.8624 ***	-2.1918	-4.7420 ***
LTR	-1.4067	-5.7166 ***	-3.1137 *	-6.1491 ***	-1.3999	-9.0180 ***	-2.7752	-11.999 ***

Source: Author's own computation

Table 4.2: Unit root test Zimbabwe

Variables	**Dickey-Fuller GLS**				**Phillips-Perron**			
	Constant		Trend & Intercept		Constant		Trend & Intercept	
	Level	Δ	Level	Δ	Level	Δ	Level	Δ
LGDP	-3.3994 ***	-6.5990 ***	-3.4060 **	-6.6400 ***	-3.3686 **	-7.5275 ***	-3.3241 *	-7.3264 ***
LEC	-0.6356	-4.9512 ***	-1.8025	-5.0235 ***	-1.2079	-4.9373 ***	-1.8124	-5.0119 ***
LCO2	-0.6448	-4.3878 ***	-1.8356	-4.5462 ***	-1.2333	-4.5802 ***	-1.7827	-5.7531 ***
LKF	-1.3732	-4.7352 ***	-1.8731	-4.7687 ***	-1.4560	-4.7266 ***	-1.9352	-4.6313 ***
LTR	-2.6298	-7.8825	-3.0828	-8.1526	-3.3385	-8.2270	-3.2519	-7.8619

	**	***	*	***	**	***	*	***

Source: Author's own computation

The study performed the DF-GLS and PP unit root test as shown in Tables 4.1 and 4.2 above for South Africa and Zimbabwe, respectively. The results of both DF-GLS and PP tests in Table 4.1 shows that the variables are stationary at first difference for South Africa, that is to say, they are integrated of I(1). However, in Table 4.2, the results shows that LEC, LCO2 and LKF are stationary at first difference, while LGDP and LTR are stationary at both level and first difference for Zimbabwe. The study, however, will estimate the relationships utilising the variables at first difference I(1) for better analysis and this makes it suitable to deploy the ARDL model proposed by Pesaran *et al.* (2001).

Table 4.3: Optimal Lag length criterion South Africa

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-117.5662	NA	0.006035	9.078977	9.318946*	9.150332
1	-87.07384	47.43253*	0.004171*	8.672136*	10.11196	9.100270*
2	-66.63457	24.22432	0.007237	9.009968	11.64964	9.794880

Source: Author's own computation

Table 4.4: Optimal lag length criterion Zimbabwe

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-277.2299	NA	826.0890	20.90592	21.14589*	20.97727
1	-247.3946	46.41041*	599.4838*	20.54775*	21.98757	20.97588*
2	-227.1662	23.97446	20.90120	20.90120	23.54087	21.68611

Source: Author's own computation

The unit root results revealed that the variables are integrated of I(1) and the study performed the optimal lag length criterion as shown in Tables 4.3 and 4.4 above to check for optimal number lags to utilise in the study. The results shows that only one lag can be utilised for estimation of short and long run relationships for both South Africa and Zimbabwe as shown by the LR, FPE, AIC and HQ criterions. The study continues to perform the cointegration relationships utilising the ARDL Bounds test as shown in Table 4.5 below.

Table 4.5: Bounding test to cointegration

Country	F-statistic	Critical Values

		1%		5%		10%	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
South Africa	10.03375 ***	3.29	4.37	2.56	3.49	2.20	3.09
Zimbabwe	14.07394 ***	3.29	4.37	2.56	3.49	2.20	3.09

Source: Author's own computation. Note: (***) indicates 1% level of significance

The study performed the ARDL Bounds test for cointegration to check for long run relationships among the variables in the model. The f-statistic for South Africa and Zimbabwe are 10.03375 and 14.07394 respectively that are above the critical values at both 1%, 5% and 10% level of significance. This implies that we reject the null hypothesis of no long run relationships among the variables and conclude that there is indeed presence of long run relationships. The study will estimate both the short and long run relationships utilising the equations 3.3 to 3.12 given in Section 3 of the study above.

Table 4.6: Short run relationships. Dependent variable: DLGDP

Variable	South Africa	Zimbabwe
DLGDP(-1)	-0.163332 (0.4320)	-0.265691 (0.2043)
DLEC	-0.736586 (0.0965) *	-0.465795 (0.6147)
DLCO2	-22.02384 (0.1361)	74.42289 (0.0010) ***
DLKF	0.394022 (0.2648)	0.600246 (0.0282) **
DLTR	0.085103 (0.0541) *	-0.240171 (0.0751) *
ECT(-1)	-1.163332 (0.0000) ****	-1.265691 (0.0000) ***
R-Squared Adj R-Squared DW Stat	0.805757 0.790218 2.165031	0.838970 0.826088 2.192723

Source: Author's own computations, Note: Figure in parenthesis are p-values

The study estimated short run relationships as shown in Table 4.6 above for both South Africa and Zimbabwe. The results reveal that there is a negative short run relationship between renewable electricity consumption and economic growth in both South Africa and Zimbabwe. A 1% increase in renewable electricity consumption in South Africa in the short run will significantly result in economic growth declining by 0.74%, ceteris paribus. However, a 1% increase in renewable electricity consumption in the short run will insignificantly result in economic growth declining by 0.47%, ceteris paribus. These results are consistent with the studies of Stungwa *et al.* (2022), Ha and Ngoc (2021) and Shahbaz (2015). These results entail that renewable electricity consumption has not been able to boost economic growth in the short run in both countries. This call for policy makers and governments of South Africa and Zimbabwe to revise policies on renewable electricity consumption so it can boost economic growth in the short run.

Furthermore, the results reveal a negative relationship for South Africa and a positive relationship for Zimbabwe between CO2 emissions and economic growth in the short run. A 1% increase in CO2 emissions in South Africa in the short run insignificantly result in economic growth declining by 22.02%, ceteris paribus. This is consistent with the results of Hlongwane and Daw (2022). However, a 1% increase in CO2 emissions in Zimbabwe in the short run will significantly result in economic growth rising by 74.42%, ceteris paribus. These results indicate that Zimbabwe is heavily reliant on non-renewable electricity consumption and fossil fuels to boost its economic growth. This call for governments of both countries, especially the government of Zimbabwe to review its CO2 emission policies to reduce heavy reliance on fossils and reduce environmental degradation caused by air pollution.

Moreover, the results reveal a positive relationship between capital formation and economic growth for both South Africa and Zimbabwe in the short run. A 1% increase in capital formation in the short run in South Africa will insignificantly result in economic growth rising by 0.39%, ceteris paribus. However, a 1% rise in capital formation in the short run in Zimbabwe significantly result in economic growth rising by 0.60%, ceteris paribus. These results are consistent with the study of Khobai and Le Roux (2017). These results entail that capital formation plays an important role on the growth of the two economies in the short run. These results call for the government and policy makers of both countries to boost an environment favourable for investment as it is crucial for economic growth.

Moreso, the results reveal a positive relationship for South Africa and a negative relationship for Zimbabwe between trade and economic growth in the short run. A 1% increase in trade in the short run in South Africa will significantly result in economic growth rising by 0.09%, ceteris paribus. This is consistent with the results of Khobai and Le Roux (2017). However, a 1% increase in trade in the short run in Zimbabwe will significantly result in economic growth declining by 0.24%, ceteris paribus. This is inconsistent with the results of Khobai and Le Roux (2017). This calls for the government of Zimbabwe to revise its trade policies as trade has not been able to boost economic growth.

The R-squared for South Africa is 0.805757, meaning that 80.58% of variation in the economic growth is explained by the independent variables while the remaining 19.42% is explained by the error term. The R-squared for Zimbabwe is 0.838970, meaning 83.90% of variation in economic growth is explained by the independent variables while 16.10% is explained by the error term. These results show a goodness of fit for the model as it is highly recommended that it should be 70% and above for a reliable model. The ECT terms are negative and statistically significant for both South Africa and Zimbabwe respectively. For South Africa, the ECT is -1.16332 meaning that 116% of the error in economic growth are corrected annually towards long run equilibrium. While, for Zimbabwe the ECT is -1.265691 meaning that 127% of the errors in economic growth are corrected annually towards long run equilibrium. The study continues to perform long run relationships as shown in Table 4.7 below.

Table 4.7: Long run relationships. Dependent variable: LGDP

Variable	South Africa ARDL (1,0,1,0,1)	Zimbabwe ARDL (1,0,1,1,0)
DLEC	-0.633169 (0.0745) *	0.368016 (0.6110)
DLCO2	-42.15859 (0.1063)	0.564110 (0.9906)
DLKF	0.338701 (0.2311)	0.938682 (0.0725) *
DLTR	-0.114590 (0.2963)	-0.189755 (0.1238)
C	-0.005531 (0.9825)	0.028109 (0.9808)

Source: Author's own computations, Note: Figure in parenthesis are p-values

The study estimated the long run relationships for both South Africa and Zimbabwe as shown by the results in Table 4.7 above. The results reveal a negative relationship for South Africa and a positive relationship for Zimbabwe between renewable electricity consumption and economic growth. A 1% increase in renewable electricity consumption in the long run in South Africa significantly result in economic growth declining by 0.63%, ceteris paribus. These results are inconsistent with the study of Khobai and Le Roux (2017) and Stungwa *et al.* (2022). However, a 1% increase in renewable electricity consumption in Zimbabwe in the long run insignificantly result in economic growth rising by 0.37%, ceteris paribus. These results entail that renewable electricity consumption plays an important role on economic growth in Zimbabwe while it has not been able to influence economic growth in South Africa. This calls for the South African government, Eskom, and policymakers to review policies on renewable energy consumption so it can boost economic growth in South Africa.

Furthermore, there is a negative relationship in South Africa and a positive relationship in Zimbabwe between CO2 emissions and economic growth in the long run. A 1% rise in CO2 emissions in the long run in South Africa insignificantly result in economic growth declining by 42.16%, ceteris paribus. The results are consistent with the studies of Hlongwane and Daw (2022) and Khobai and Le Roux (2017). However, a 1% rise in CO2 emissions in the long run in Zimbabwe insignificantly result in economic growth rising by 0.56%, ceteris paribus. These results entail that CO2 emissions has a detrimental effect on economic growth in South Africa while boosting economic growth in Zimbabwe. This calls for government of both countries to revise their CO2 emissions in a way consistent with the growth of their economies.

Moreover, the results reveal a positive long run relationship between capital formation and economic growth in both countries. A 1% increase in capital formation in South Africa in the long run insignificantly result in economic growth rising by 0.34%, ceteris paribus. However, a 1% increase in capital formation in the long run in Zimbabwe significantly result in economic growth rising by 0.94%, ceteris paribus. These results entail that capital formation plays an important role on the growth of these economies. This calls for the government of both countries to create an environment favourable for investment as it boosts economic growth. These results are consistent with the results of Khobai and Le Roux (2017).

Moreso, there is a negative long run relationship between trade and economic growth in both countries. A 1% increase in trade in the long run in South Africa will insignificantly result in economic growth declining by 0.11%, ceteris paribus. A 1% rise in trade in the long run in

Zimbabwe insignificantly result in economic growth declining by 0.19%, ceteris paribus. These results entail that trade has not been able to boost economic growth in the long run in both countries. This calls for the government of both countries to review and revise policies on trade so it can be able to boost economic growth. The study continues to perform diagnostics tests as given in the Table 4.8 below.

Residual diagnostics test

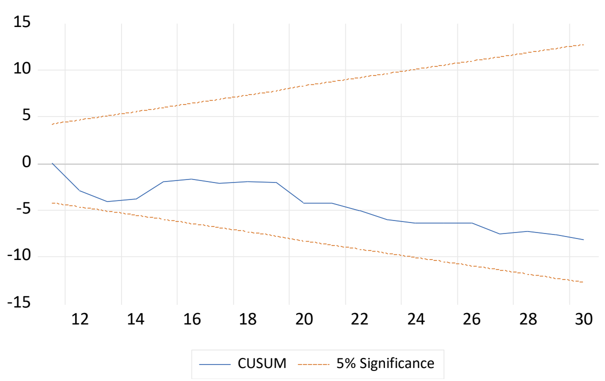
Table 4.8: Normality, heteroskedasticity, serial correlation and stability test

Country	Normality	Serial Correlation	Heteroskedasticity	Ramsey's RESET test
South Africa	4.2601 (0.1188)	0.5960 (0.4496)	1.0192 (0.4479)	0.3732 (0.5485)
Zimbabwe	0.3169 (0.8535)	1.1877 (0.2894)	1.1534 (0.3713)	0.5433 (0.4701)

Source: Author's own computation. Note: Figures in parenthesis are p-values

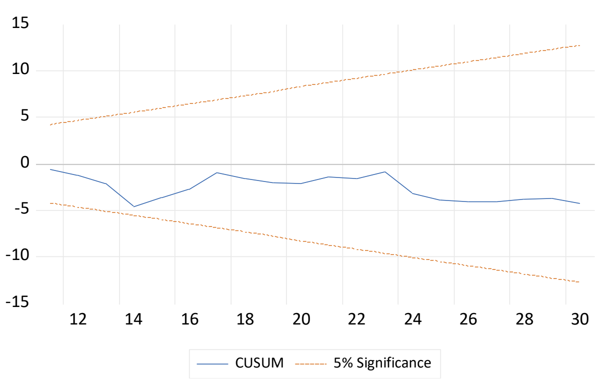
The study performed diagnostic tests of normality, serial correlation, heteroskedasticity and model specification as shown in Table 4.8 above. The serial correlation test selected the Breusch-Godfrey LM serial correlation test, and the results reveal that there is no serial correlation in the estimated model. The study performed the Breusch-Pagan heteroskedasticity test and the results reveal that there is no heteroskedasticity in the selected model. The study performed the Jarque-Berra normality test, and the results reveal that the residuals are normally distributed. The study performed the Ramsey's RESET test for misspecification and the results reveal that the model is correctly specified.

Figure 4.1: CUSUM South Africa



Source: Author's computation

Figure 4.2: CUSUM Zimbabwe



Source: Author's computation

The study performed the stability of the coefficients, the cumulative sum of recursive residuals (CUSUM) test is conducted for both countries. The CUSUM graphs are presented in Figures 4.1 and 4.2 above indicate model stability for both countries as the plots are within 5% confidence interval critical bands.

5. CONCLUSION AND RECOMMENDATIONS

The study investigates the relationship between renewable electricity consumption and economic growth from 1990 to 2019 in South Africa and Zimbabwe. The study performed the Dickey-Fuller Generalised Least Squares (DF-GLS) and Phillips-Perron (PP) unit root test to determine the order of integration and avoid problem of spurious regressions. The study performed the ARDL Bounds test and found cointegration relationships among the variables. The study employed the ARDL model to check for both short and long run relationships between the variables in the model. The study therefore makes the following policy recommendations based on empirical evidence:

Firstly, the government of South Africa and Zimbabwe need to revise policies on renewable electricity consumption it can be able to significantly boost economic growth in both in the short and long run period. This can be done by speeding up the process of renewable energy in Zimbabwe as it affects positively, while following a reveal approach in South Africa as it has been found to have a detrimental effect.

Secondly, the South African government needs to revise its CO2 policies as it was found to have a detrimental effect on economic growth. In Zimbabwe, however, CO2 has been found to boost economic growth and the policymakers can review the policies on CO2 as this indicates heavy reliance on fossils.

Thirdly, the governments and policymakers of both countries need to continue creating an environment favourable for capital formation as it has been boosting growth of their economies. This can be done by relaxing policies that are detrimental for investment opportunities in both countries.

Finally. The governments of both countries must revise policies on trade as it is detrimental for the growth of their economies. This can be done by creating an environment favourable for export promotion as it is known that these two countries rely mostly on imports from other countries.

The main objective of the study was to investigate the relationship between renewable electricity consumption and economic growth in South Africa and Zimbabwe. This was achieved by employing an ARDL model to reveal both short and long run relationships. In conclusion, the renewable electricity consumption was found to have a negative long run relationship while in the short run the results are negative in South Africa and positive in the Zimbabwe. In the future, studies must consider employing other models and more observations to reveal new insights in the field.

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