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Renewable Energy Consumption and Economic Growth in Southern African Development Community Region

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Abstract
This study empirically analyzed the effects of renewable energy consumption on economic growth in Southern African Development Community using longitudinal data for a panel of 16 countries during the sample period 2000-2019. The methodological approach used applied the Breusch-Pagan Lagrangian multiplier test and Hausman test procedures. Based on estimates of the fixed effects model, empirical results show that an increase in renewable energy consumption had a statistically significant and positive effect on economic growth in the region. The estimated R-squared shows that approximately 3.4 percent total variation in economic growth was explained by renewable energy consumption and total natural resource rents. The computed F-statistic (= 7.88; $p < 0.01$) confirms significance of the model; while the interclass correlation value shows that approximately 52.6 percent of the variance was due to differences across panels.
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1. Introduction

Sustainable consumption of renewable clean energy is a precondition for economic growth, human prosperity and sustainable development as opposed to non-renewable resources such as fossil fuels - coal, oil and gas, which cause harmful greenhouse gas emissions, like carbon dioxide. Therefore, transitioning from fossil fuels, which presently account for the substantial share of emissions, to renewable energy remains central to addressing the globally intensifying crisis of climate change. The renewable energy mix countries should consider transitioning towards include solar energy, wind energy, geothermal energy, ocean energy, hydropower, and bioenergy - largely in rural areas.

In recognising the fundamental importance of clean energy on human life, the United Nations (UN) General Assembly, in 2015, adopted the 2030 Agenda for sustainable development and sustainable development goals (SDGs), which include a dedicated and distinct goal on energy (SDG 7) which focuses on the need to "*ensure access to affordable, reliable, sustainable and modern energy for all*". Ensuring access to affordable, reliable, sustainable, and modern energy for all is expected to open prospects for billions of people through new economic opportunities and jobs, empowerment of women, children and youth, better education and health, equitable and inclusive communities, and greater protection from and resilience to climate change.

In the Southern African Development Community (SADC) region, SADC bloc has enacted several strategic plans for energy development in the region. Such plans include the SADC Protocol on Energy (1996), SADC Energy Cooperation Policy and Strategy (1996), SADC Energy Action Plan (1997), SADC Energy Activity Plan (2000), SADC Regional Energy Access Strategy and Action Plan (2010), SADC Regional Infrastructure Development Master Plan and Energy Sector Plan (2012), SADC Renewable Energy and Energy Efficiency Strategy and Action Plan 2016-2030, and SADC Regional Energy Access Strategy and Action Plan 2020-2030.

The objective of this study was to assess the effect of renewable energy consumption on economic growth in a panel of sixteen countries in Southern African Development Community during the period 2000-2019. The paper is structured as follows: Section 2 provides related literature, section 3 presents the methodology and estimation procedure, section 4 presents and analyses the findings, and section 5 provides conclusion and policy recommendations.

2. Literature

Following Gozgor, Lau & Lu (2018), there are four hypotheses which explain the causal nexus between energy consumption and economic growth. These hypotheses in the economic growth hypothesis, the conservation hypothesis, the feedback hypothesis and the neutrality hypothesis. The growth hypothesis states that energy consumption directly causes economic growth, while the conservation hypothesis indicates that economic growth causes energy consumption. The feedback hypothesis suggests bidirectional causality between energy consumption and growth, while the neutrality hypothesis implies that there does not exist a statistically significant causality between economic growth and energy consumption. From an empirical standpoint, some studies have been conducted and analysed how renewable energy consumption affects economic growth in different countries and regions. The findings reported, however, differ considerably depending on choices of the datasets and econometric or statistical methods used.

Apergis & Payne (2012) used a panel error correction model (PECM) and found bidirectional causality between renewable energy consumption and economic growth in a panel of 80 nations during the period 1990-2007. Jebli & Youssef (2015) used the ordinary least squares (OLS), dynamic ordinary least squares (DOLS), and fully-modified ordinary least squares (FMOLS) methods, and found the validity of the growth hypothesis for the significant positive effect of renewable energy consumption on economic growth, and the unidirectional causality from renewable energy consumption to economic growth in a panel of 69 countries during the period 1980-2010. Bhattacharya, Paramati, Ozturk & Bhattacharya (2016) analysed the impact of renewable energy consumption on economic growth in thirty-eight major renewable energy consuming countries in the world during the period 1991-2012. Panel estimates indicate cross-sectional dependence and heterogeneity, and long-run output elasticities show that renewable energy consumption had a significant positive impact on economic growth of 57% of countries.

Esen & BayraK (2017) analysed whether more energy consumption support economic growth in a sample of 75 net energy-importing nations during the ample period 1990-2012. Countries were classified based on their energy-import dependence and income levels. Findings indicates evidence of statistically significant and positive relationships between energy consumption and long-run economic growth. Based on the finding that the observed positive effect of energy consumption on economic growth decreased as output growth increased, the study concluded that efficient use of energy is an important catalyst for economic growth and development. Twerefou, Iddrisu & Twum (2018) asserted that availability of reliable energy remains crucial for economic growth and assessed the relationship between energy consumption and economic growth in Western Africa using panel cointegration methods. Results from the analysis indicate that in the short-run, there was no significant causal relationship between energy consumption and growth. In the long-run, energy consumption had a significant and positive impact on economic growth in the region.

Gozgor, Lau & Lu (2018) examined the effects of renewable energy consumption on economic growth in a panel of twenty-nine countries in the Organisation for Economic Cooperation and Development (OECD) during the sample period 1990-2013. The study used the autoregressive distributed lag (ARDL) model and panel quantile regression (PQR) approaches for estimation. Results indicate that not only did economic complexity, renewable energy consumption led to improvements in economic growth, thus supporting the growth hypothesis between renewable energy consumption and economic growth in the panel of countries covered in the analysis.

Nondo, Kahsai & Schaeffer (2010) analysed the relationship between energy consumption and economic growth in the long-run in a panel of 19 African countries in the COMESA bloc during the sample period 1980-2005. Results indicate strong empirical evidence that economic growth and energy consumption had a cointegrating relationship, and there was bidirectional causality between renewable energy consumption and economic growth. Sebri & Ben-Salha (2014) used an ARDL model and found evidence of the bidirectional causal relationship between renewable energy and economic growth in BRICS nations during 1971-2010. Kasperowicz & Štreimikienė (2016) examined the effect of energy consumption on economic growth in V4 countries and 14 old member states of the European Union (EU) during 1995-2012. Energy consumption had a significant and positive effect on economic growth in V4 countries than in the old EU nations.

Shahbaz, van Hoang, Mahalik & Roubaud (2017) investigated the relationship between energy consumption and economic growth in India using nonlinear and asymmetric analysis and results show that energy consumption shock had significant impacts in economic growth. Sadorsky (2009) analysed the nexus between renewable energy consumption and economic growth in G7 nations and found evidence of causality from renewable energy to economic growth during 1980-2005. Salim & Rafiq (2012) used a Granger causality test and found bidirectional causality between the renewable energy and economic growth in six emerging economies during 1980-2006 in the short-run, and significant causality from economic growth to renewable energy in the long-run.

3. Methodology

3.1. Data

The study utilized longitudinal data on economic growth rate, renewable energy consumption and total natural resource rents for a panel of sixteen Southern African Development Community (SADC) member states during the sample period 2000-2019. Annual data for all the variables was collected from the World Bank's publicly and freely accessible online database. The variables on which data was collected include gross domestic product (GDP) growth rate; renewable energy consumption (% of total final energy consumption) and total natural resources rents (% of GDP). The GDP growth rate was the dependent variable, while renewable energy consumption, and total natural resource rents were explanatory variables. Table 1 provides descriptions of these variables.

Table 1: Data description

Code	Name	Description
NY.GDP.MKTP.KD.ZG	GDP growth rate (annual %)	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2015 prices, expressed in U.S. dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of products.
EG.FEC.RNEW.ZS	Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable energy in total final energy consumption.
NY.GDP.TOTL.RT.ZS	Total natural resources rents (% of GDP)	Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.
Note: The source organisation for GDP growth rate is the *World Bank national accounts data and the Organisation for Economic Co-operation and Development (OECD) National Accounts data files*; while the source organisation for renewable energy is the World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency (IEA), and the Energy Sector Management Assistance Program; and the source organisation for total natural resource rents is the World Bank staff estimates based on sources and methods described in the World Bank's The Changing Wealth of Nations.		

3.2. Unit root tests

Unit root tests on the longitudinal series were conducted using the Harris-Tzavalis (HT) panel unit root test technique. The selection and use of the HT technique was based on the rationale that the longitudinal dataset was strongly balanced and time periods (T) relative to the number of panels (N) which identify the asymptotic distribution of the panel stationarity test statistic were balanced (Hlouskova & Wagner, 2006). Based on the sequential limit theorem, the HT unit root test method used treats the number of time periods (T) as fixed, while the number of panels in the data matrix is assumed to approach infinity within the given time period (Harris & Tzavalis, 1999). Stationarity tests were therefore conducted on economic growth rate, renewable energy consumption and total natural resource rent series prior to estimation of empirical results for inferential purposes.

3.3. Estimation procedure

The econometric procedure followed in selecting the appropriate estimation model was based on review of three panel data models; namely pooled ordinary least squares (OLS) regression, random effects (RE) and fixed effects (FE) models (Ganyaupfu, 2014a and 2014b). The Breusch-Pagan Lagrangian Multiplier and Hausman test techniques were used to select the suitable models.

Pooled OLS model: $Y_{it} = \alpha + X'_{it}\,\beta\left(\alpha_i - \alpha + \varepsilon_{it}\right)$ (1)

Random effects model: $Y_{it} = \alpha + X'_{it}\,\beta + \left(u_i + \upsilon_{it}\right); \upsilon_{it} \sim IID\left(0, \sigma_v^2\right)$ (2)

Fixed effects model: $Y_{it} = \alpha_i + X'_{it}\,\beta + u_i + \varepsilon_{it}$ (3)

The Breusch and Pagan Lagrangian Multiplier test was run on the RE model to properly select between the Pooled OLS and RE model. The respective LM test was run based on the specification:

$$LM_u = \frac{nT}{2(T-1)}\left[\frac{\sum\left(\sum \varepsilon_{it}\right)^2}{\sum\sum \varepsilon_{it}^2} - 1\right]^2 = \frac{nT}{n(T-1)}\left[\frac{\sum (T)\bar{\varepsilon}_i}{\sum\sum \varepsilon_{it}^2} - 1\right] \sim \chi^2(1) \quad (4)$$

Following rejection of the hypothesis that the pooled OLS regression was appropriate (Table 5), the Hausman test was run to choose between RE and FE models based on the specification below:

$$H = \left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right)' \left[\left(V\left(\hat{\beta}_{FE}\right) - V\left(\hat{\beta}_{RE}\right)^{\wedge}(-1)\right)\right]\left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right) \quad (5)$$

The Hausman test results were used to select the suitable model between random effects and fixed effects at 5% significance level. Differences across panels were measured by interclass correlation (ρ); which approaches 1 if the respective individual effects dominate the idiosyncratic error.

3.4. Estimation model
The econometric estimation model used was a single equation model formulated as below:

$$GDP\_gr_t = \alpha + \beta(REC)_t + \lambda(TNRR)_t + u_{it}$$

where GDP_gr represents the GDP growth rate, REC denotes the renewable energy consumption, $TNRR$ signifies total natural resource rents, α is a constant term, while β and λ are coefficients of the associated explanatory variables, and u_{it} is the error term.

4. Results and Analysis

The results presented herein include panel unit root tests, summary statistics and estimates of the random effects model, Breusch and Pagan Lagrangian multiplier test and fixed effects model.

4.1. Unit root tests

Table 2: Harris-Tzavalis (HT) panel unit root tests†*

Variable	z-statistic	p-value	Decision	Conclusion
GDP growth rate	-2.237*	0.012	Reject H_0	Stationary
Renewable energy consumption	0.124	0.549	Don't reject H_0	Non-stationary
D. Renewable energy consumption	-23.366*	0.000	Reject H_0	Stationary
Total natural resource rents	-6.478*	0.000	Reject H_0	Stationary

† unit root tests were conducted with no time trend not included; and * indicates rejection of the null hypothesis that (H_0) panels contain unit roots versus the alternative hypothesis (H_1) that panels are stationary at 5% significance level.

Panel unit root tests results (Table 2) indicate that the panels for GDP growth rate, and total natural resource rents were stationary at level, while panel renewable energy consumption was stationary at first difference. These results confirm that econometric analysis could be conducted using the appropriate panel data estimation method(s).

4.2. Summary statistics
Descriptive statistics computed for each variable include the arithmetic mean, standard deviation, minimum and maximum values, sample size, number of panels and number of time periods.

Table 3: Descriptive statistics†

Variable series		Mean	Std. dev	Min	Max	Obs
GDP growth rate	overall	3.980	4.194	-17.668	19.675	N = 320
	between		1.578	0.451	6.532	n = 16
	within		3.905	-14.140	23.203	T = 20
Renewable energy consumption	overall	58.231	30.693	0.71	98.340	N = 320
	between		31.354	1.116	96.688	n = 16
	within		4.185	46.504	73.974	T = 20
Total natural resource rents	overall	7.843	9.543	0.001	55.874	N = 320
	between		8.976	0.006	33.610	n = 16
	within		3.912	-14.937	30.108	T = 20

Descriptive statistics (Table 3) indicate that the total number of observations for all variables was three hundred and twenty (N = 320), each with a panel comprising sixteen countries (n = 16) across twenty years (T = 20). Relative to arithmetic means, large variations (standard deviations) occurred on GDP growth rate (mean = 3.98%; sd = 4.19%) which ranged between -17.67% and 19.68%, and total natural resource rents (mean = 7.84; sd = 9.54) ranging between 0.00% and 55.87%.

4.3. Breusch and Pagan Lagrangian Multiplier (LM) test
The Breusch and Pagan LM test procedure was applied on estimates of the RE model (Table 4) to evaluate whether the pooled OLS regression was appropriate model to use for analysis.

Table 4: Random effects model

R-squared: within = 0.038				obs per group: min = 20		
between = 0.200				: avg = 20.0		
overall = 0.048				: max = 20		
				Wald chi2(2) = 11.81		
corr(u_i,x) = 0 (assumed)				Prob > chi2 = 0.0027		
GDP growth rate	Coeff.	Std. Err	z-stat	P > | z |	95% Conf. Int	
Renewable energy consumption	0.008	0.013	0.66	0.507	-0.017	0.034
Total natural resource rents	0.108	0.037	2.91	0.004	0.035	0.181
_cons	2.626	0.807	3.25	0.001	1.043	4.210
sigma_u	1.235					
sigma_e	3.913					
rho	0.090	(fraction of variance due to u_i)				

The Breusch and Pagan Lagrangian Multiplier test for random effects estimates (Table 5) rejected the null hypothesis that the pooled ordinary least squares (OLS) regression model was suitable.

Table 5: Breusch and Pagan Lagrangian Multiplier test for random effects model

GDP growth rate [Country, t] = Xb + u [Country] + e [Country, t]		
	Var	sd = sqrt(Var)
GDP growth rate	17.596	4.194
e	15.313	3.913
u	1.526	1.235
Test: Var (u) = 0	Chibar2(01) = 13.55	Prob > chibar2 = 0.0001

The fixed effects model was estimated and results presented in (Table 6) to make the correct choice of an appropriate model between random effects model and fixed effects model based on estimates obtained from the Hausman test procedure.

Table 6: Fixed effects model

R-squared: within = 0.049			obs per group : min = 20			
between = 0.159			: avg = 20.0			
overall = 0.034			: max = 16			
			F (2, 302) = 7.88			
corr(u_i, Xb) = -0.9183			Prob > F = 0.001			
GDP growth rate	Coeff.	S.E.	t-stat	P > | t |	95% Conf. Int	
Renewable energy consumption	0.114	0.052	2.18	0.030	0.011	0.218
Total natural resource rents	0.170	0.056	3.02	0.003	0.059	0.281
_cons	-4.043	3.056	-1.32	0.187	-10.058	1.970
sigma_u	4.124					
sigma_e	3.913					
rho	0.526	(fraction of variance due to u_i)				
F test that all u_i = 0:	F (15, 302) = 3.13		Prob > F = 0.0001			

The Hausman test (Table 7) was run to select the appropriate model between RE and FE models.

Table 7: Hausman test results

	Coefficients			
	(b) FE1	(B) RE1	(b-B) Diff	sqrt(diag(V_b–V_B))
Renewable energy consumption	0.114	0.008	0.106	0.051
Total natural resource rents	0.170	0.108	0.062	0.043
Test H_o: difference in coefficients not systematic:				
chi2(2) = 6.95			Prob > chi2 = 0.0310	

The Hausman test was conducted to assess whether individual effects are random. Given the null hypothesis that the random effects model is consistent, and the alternative hypothesis in preference of the fixed effects, results from the Hausman test performed imply rejection of the null hypothesis that the random effects model was appropriate. The coefficient estimates of the fixed effects model were therefore consistent; and selected for use in making empirical inferences in this study.

Econometric estimates of the fixed effects model indicate that renewable energy consumption had a statistically significant positive effect on GDP growth SADC. Results indicate that a 1 percentage point increase in renewable energy consumption (as a share of total final energy consumption) led to 0.11 percentage points rise in economic growth rate. Similarly, total natural resource rents had a significant positive effect on economic growth. Estimates show that a rise in total natural resource rents (as a share of GDP) was associated with 0.17 percentage points increase in economic growth. These results therefore confirm that renewable energy stimulate economic growth in the region.

Overall, the computed R-squared estimate of the fixed effects model indicates that approximately 3.4 percent total variation in economic growth in the respective region was explained by renewable energy consumption, and total natural resource rents. Furthermore, the computed F-statistic (7.88; $p < 0.01$) indicate that significance of the estimated model; while the interclass correlation reveal that about 52.6 percent of the variance computed from the suitable fixed effects model was due to differences across panels of the sample countries.

5. Conclusion and recommendation

This paper estimated individual effect of renewable energy consumption (as a proportion of total final energy consumption) on economic growth in the SADC region during the period 2000-2019. Econometric estimates show that increases in renewable energy consumption had a significant and positive impact on economic growth during the sample period under review. Concomitantly, total natural resource rents had a more pronounced positive effect on economic growth in the region.

These results are consistent with findings reported by Apergis & Payne (2012) who found evidence of bidirectional causality between renewable energy consumption and economic growth, and Jebli & Youssef (2015) who found the validity of the growth hypothesis regarding the significant positive effect of renewable energy consumption on economic growth, and unidirectional causality from renewable energy consumption to growth. Bhattacharya, Paramati, Ozturk & Bhattacharya (2016) similarly found that renewable energy consumption had a significant positive impact on growth. Kasperowicz & Štreimikienė (2016), Esen & BayraK (2017) and Gozgor, Lau & Lu (2018) also found evidence of positive effects of energy consumption on economic growth.

The findings from this study suggest that governments, energy planners, international cooperation agencies and associated bodies for the SADC region need to act together and channel their effort towards boosting investments in renewable energy for low carbon growth in the region. Moreover, renewable energy consumption should be encouraged in the region to promote economic growth without damaging the environment, and contribute to reducing greenhouse gas emissions.

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