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Electricity Consumption and Economic Growth in Southern African Development Community Region

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Abstract
This study empirically analyzed the effects of access to electricity by distinct population segments on economic growth in the Southern African Development Community using longitudinal data for a panel of 12 countries during the sample period 2010-2020. The methodological approach used followed applied the Breusch-Pagan Lagrangian multiplier test and Hausman test procedures. Based on the fixed effects model estimates, empirical results show that increases in percentages of rural and urban populations with access to electricity distinctly had statistically significant and positive effects on economic growth; with rural population access to electricity having had a more noticeable significant positive effect on economic growth than the rural population in the region. The estimated R-squared shows that approximately 8.0 percent total variation in economic growth was explained by the shares of the total population, rural population, and urban population. The F-statistic (= 6.48; p < 0.05) reveals significance of the model; while the interclass correlation value shows that approximately 80.1 percent of the variance was due to differences across panels.
Keywords: electricity, access, population, urban, rural, economic growth
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1. Introduction

Access to reliable energy such as electricity, among others, has a substantial positive impact on economic growth and development, health, education, and efficient safe water supplies and communication services (International Energy Agency, 2014). Starr (1972) and Sarkodie & Adams (2020) indicate that electricity access and consumption have high positive correlations with economic growth and other indicators of that enhance and/or improve people's lifestyles and wellbeing.

In efforts to improve the performance of the electricity sector, the Southern African Development Community (SADC) has so far enacted numerous strategic plans for energy development in the region. The plans include the SADC Protocol on Energy (1996), SADC Energy Cooperation Policy and Strategy (1996), SADC Energy Action Plan (1997), SADC Regional Energy Access Strategy and Action Plan (2010) and SADC Regional Energy Access Strategy and Action Plan 2020 to 2030. To date, nine member states have merged their electricity grids into the Southern African Power Pool (SAPP), reducing costs and creating a competitive common market for electricity in the region. In addition, SADC established the Regional Electricity Regulatory Association which has effectively helped in harmonising the region's regulatory policies on energy and its subsectors.

Despite the progress made so far, the SADC (2019) Regional Infrastructure Development Master Plan Assessment report indicates that the SADC region still faces significant energy challenges with regards to electricity access and consumption. The report indicates that merely 32% of rural areas in the region have access to electricity, and the region falls behind in Africa regarding access to electricity. In addition, the report highlights that about 50% of the SADC region's residents have access which is equivalent to the weighted average for Sub-Saharan Africa (SSA), while countries in North Africa have reached 100% access to electricity.

The objective of this study was to analyse the effects of access to electricity by distinct population segments on economic growth in a panel of twelve countries in the Southern African Development Community during the period 2010-2020. 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

The International Energy Agency's (IEA) World Energy Outlook (2013) report states that more than 1.2 million people worldwide did not have access to electricity in 2011, and most of them live in developing nations with Africa being the region most affected by the lack of electrification, specifically Sub-Saharan Africa. Khandker, Barnes & Samad (2009) suggest that lack of access to electricity presents as one of the key barriers to economic growth. Access to electricity is therefore an essential condition for improving economic growth, living conditions and human development.

Although electricity alone is undisputedly not sufficient to enhance all the conditions for economic growth, it is apparently essential for basic human needs and economic activity (IEA, 2013). In practice, access to electricity markedly improves socioeconomic conditions in developing nations through conduits such as health, education, income, and environment (Kanagawa & Nakata, 2008). Blimpo & Malcolm (2019) argue that access to reliable electricity is a prerequisite for economic transformation of rural and urban economies in Africa, yet access to electricity is low in this region.

Davis (1998) focused on changes in energy consumption patterns by households in rural areas following electrification, and the effect of access to electricity on economic growth. Using household survey data, and the study described the evolutions of energy expenditures and fuel use and found weak evidence that electricity access enhanced energy transition and economic growth. Spalding-Fecher & Matibe (2003) estimated the externalities of electrification in South Africa such as air pollution impacts on human health, damages from greenhouse gas emissions, and avoided health costs from electrification, and potential such externalities had on economic growth. Results provide strong evidence that access to electricity significantly improved rural households' living conditions and promoted economic activities in rural economies.

Kanagawa & Nakata (2008) found significant positive correlations between economic growth, electricity consumption and human development in 120 nations. The study found that countries with higher levels of electricity consumption were ranked high in both economic activities and human development index. Bildirici, Bakirtas & Kayikci (2012) analysed the causality between electricity consumption and economic growth in developing and developed nations, including United States (US), United Kingdom (UK), Canada, Japan, China, India, Brazil, Italy, France, Turkey and South Africa. The autoregressive distributed lag results show evidence supporting the growth hypothesis for the US, Brazil, Canada and China; but there was no evidence to support the conservation hypothesis in India, Turkey, South Africa, Japan, UK, France and Italy.

Khandker, Barnes, Samad & Minh (2013) analysed the effects of electrification on incomes and expenditures of households in in Bangladesh using probit and instrumental variable (IV) quantile regressions. The study found that increased access to electricity led to improved income levels and reduced expenditure levels among households connected to the grid. The findings were consistent with prior community and household studies in developing countries which found higher expected economic activity and incomes due to improved access to electricity (Bensch, Kluve & Peters, 2011; and Rao, 2013). Bensch et al. (2011) and Rao (2013) and applied multivariate regressions in Rwanda and India; respectively, and found that increased access to electricity led to improved income benefits due to electrification projects in deprived areas.

Runganga & Mishi (2020) found that electricity consumption had a long run impact on economic growth. Sarkodie & Adams (2020) analysed effects of human development and income inequality on access to electricity in Sub-Saharan Africa using data for the period 1990-2017. Nonparametric regression results with Driscoll-Kraay standard errors show that income inequality had significant negative effects on access to electricity, while income levels and human development had positive effects on access to electricity. The study recommended the strong need to improve socioeconomic conditions by reducing unemployment and income inequalities in the region's labour markets.

Thaker, Thaker, Amin & Pitchays (2019) error correction model results indicate strong evidence that electricity consumption had a significant positive impact on economic growth in Malaysia during the sample period 1971-2010. Ameyaw, Oppong, Abruquah & Ashalley (2019) found unidirectional causality from economic growth to electricity consumption in China during 1970-2014. Bekun & Agboola (2019) conducted a study in Nigeria and found evidence of a long-run relationship between electricity consumption and economic growth based on estimates of dynamic ordinary least squares (DOLS) and fully-modified ordinary least squares (FMOLS) techniques. Hassan & Kankanamge (2021) found evidence of long-run cointegration between electricity consumption and economic growth in Sri Lanka. In China, Milin et al. (2022) investigated the relationship between electricity consumption and economic growth, and found evidence from both the autoregressive distribute lag (ARDL) model and vector error correction model that electricity consumption had a significant positive effect on economic growth during the period 1995-2017.

3. Methodology

3.1. Data

The study used longitudinal data on economic growth rate and access to electricity indicators for a panel of twelve Southern African Development Community (SADC) member states during the sample period 2010-2020. 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; electricity (% of population); access to electricity, urban (% of urban population) and access to electricity, rural (% of rural population). The GDP growth rate was the dependent variable, while the three variables relating to access to electricity were the 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 the products.
EG.ELC.ACCS.ZS	Access to electricity (% of population)	Access to electricity is the percentage of population with access to electricity. Electrification data are collected from industry, national surveys and international sources.
EG.ELC.ACCS.UR.ZS	Access to electricity, urban (% of urban population)	Access to electricity, urban is the percentage of urban population with access to electricity.
EG.ELC.ACCS.RU.ZS	Access to electricity, rural (% of rural population)	Access to electricity, rural is the percentage of rural population with access to electricity.

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 three access to electricity-related indicators is the *World Bank Global Electrification Database from "Tracking SDG 7: The Energy Progress Report"* led jointly by custodian agencies: International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations (UN) Statistics Division, World Bank and World Health Organization (WHO).

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).

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:

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

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:

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

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:

$$GDP\_gr_t = \alpha + \beta(ATE_{pop})_t + \lambda(ATE_{urb})_t + \omega(ATE_{rur})_t + u_{it}$$

where GDP_gr represents the GDP growth rate, ATE_{pop} is the percentage of population with access to electricity, ATE_{urb} denotes the percentage of urban population with access to electricity, ATE_{rur} signifies the percentage of rural population with access to electricity, α is the constant term, while β , λ and ω 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
Access to electricity (% of pop)	2.349	0.990	Don't reject H_0	Non-stationary
D.Access to electricity (% of pop)	-12.335*	0.000	Reject H_0	Stationary
Access to electricity, urban (% of urban pop)	1.328	0.908	Don't reject H_0	Non-stationary
D.Access to electricity, urban (% of urban pop)	-14.523*	0.000	Reject H_0	Stationary
Access to electricity, rural (% of rural pop)	1.723	0.957	Don't reject H_0	Non-stationary
D.Access to electricity, rural (% of rural pop)	-11.511*	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) show that the panel for GDP growth rate was stationary at level, while panels of all explanatory variables were stationary at first difference. The respective explanatory variables include access to electricity (% of pop); access to electricity, urban (% of urban pop); and access to electricity, rural (% of rural pop). These results confirm that econometric estimation could be conducted using the suitable estimation technique.

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	3.445	4.261	-14.894	19.675	N =	132
	between		1.454	0.983	5.916	n =	12
	within		4.026	-13.461	18.159	T =	11
Access to electricity (% of pop)	overall	56.084	29.112	7.4	100	N =	132
	between		29.672	11.198	99.571	n =	12
	within		5.856	37.537	71.715	T =	11
Access to electricity, urban (% of urban pop)	overall	77.610	17.321	32.6	100	N =	132
	between		16.872	44.106	99.852	n =	12
	within		6.090	59.875	92.595	T =	11
Access to electricity, rural (% of rural pop)	overall	42.619	35.380	0.926	100	N =	132
	between		36.374	3.678	99.492	n =	12
	within		5.443	23.447	59.411	T =	11

Descriptive statistics (Table 3) show that the total number of observations for all variables was one hundred and thirty-two (N = 132), each with a panel comprising twelve countries (n = 12) across eleven years (T = 11). Relative to arithmetic means, large variations (standard deviations) were observed on GDP growth rate (mean =

3.44%; sd = 4.26%) which ranged between -14.89% and 19.67%, while there was moderate variation in the percentage of rural population with access to electricity (mean = 42.92; sd = 35.38) ranging between 0.93% and 100% across sampled countries.

There was low variation in the percentage of urban population with access to electricity relative to the mean of sampled nations (mean = 77.61%; sd = 17.32%). Urban population in the region had relatively highest average percentage of population (mean = 77.61%) with access to electricity, and rural population had the lowest average of people (mean = 42.62%) with access to electricity.

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 = 0.161				obs per group: min = 11		
between = 0.448				: avg = 11.0		
overall = 0.088				: max = 11		
				Wald chi2(4) = 12.08		
corr(u_i,x) = 0 (assumed)				Prob > chi2 = 0.016		
GDP growth rate	Coeff.	S.E.	z-stat	P > | z |	95% Conf. Int	
Access to electricity (% of pop)	-0.095	0.075	-1.20	0.229	-0.237	0.056
Access to electricity, urban (% of urban pop)	0.016	0.061	0.26	0.794	-0.104	0.136
Access to electricity, rural (% of rural pop)	0.033	0.042	0.78	0.434	-0.050	0.117
_cons	5.828	2.800	2.08	0.037	0.339	11.317
sigma_u	0.294					
sigma_e	3.868					
rho	0.005	(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	0.683	0.826
e	0.535	0.731
u	0.166	0.408
Test: Var (u) = 0	Chibar2(01) = 7.82	Prob > chibar2 = 0.002

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 = 0.182				obs per group : min = 11		
between = 0.394				: avg = 11.0		
overall = 0.080				: max = 11		
				F (4, 116) = 6.48		
corr(u_i, Xb) = -0.968				Prob > F = 0.000		
GDP growth rate	Coeff.	S.E.	t-stat	P > | t |	95% Conf. Int	
Access to electricity (% of pop)	-0.949	0.320	-2.96	0.004	-1.584	-0.314
Access to electricity, urban (% of urban pop)	0.345	0.171	2.01	0.047	0.005	0.685
Access to electricity, rural (% of rural pop)	0.461	0.218	2.11	0.037	0.029	0.893
_cons	8.936	5.706	1.57	0.120	-2.365	20.237
sigma_u	7.761					
sigma_e	3.868					
rho	0.801	(fraction of variance due to u_i)				
F test that all u_i = 0:	F (11, 116) = 2.63			Prob > F = 0.005		

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))
Access to electricity (% of pop)	-0.949	-0.090	-0.859	0.333
Access to electricity, urban (% of urban pop)	0.345	0.016	0.329	0.172
Access to electricity, rural (% of rural pop)	0.461	0.033	0.427	0.228
Test H_o: difference in coefficients not systematic:				
chi2(4) = 18.74			Prob > chi2 = 0.001	

The Hausman test was conducted to determine whether individual effects are random. Given the null hypothesis that the random effects model is consistent, and the alternative hypothesis in favour 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 inferences in the study.

Based on the fixed effects model estimates, the percentage of population with access to electricity had a statistically significant but negative effect on GDP growth SADC. Results indicate that a 1 percentage point increase in the share of the total population was associated with 0.95 percentage points decline in output growth rate. A decomposition of the effect of access to electricity on output growth by rural and urban populations shows that increases in proportions of both urban and rural populations with access to electricity have significant and positive effects on economic growth.

The estimated coefficients indicate that an increase in the share of urban population with access to electricity by 1 percentage point led to a rise in economic growth by 0.34 percentage points, while an increase in the proportion of the rural population with access to electricity led to 0.46 percentage points in economic growth in the region. These results indicate that an increase in the share of rural population with access to electricity had a relatively larger positive effect on output growth in SADC region than an increase in the share of the urban population.

Overall, the computed R-squared estimate of the fixed effects model indicates that approximately 8.0 percent total variation in economic growth in the respective region was accounted for by shares of the total population, rural population and urban population with access to electricity. Moreover, the computed F-statistic (6.48; $p < 0.05$) indicate that significance of the estimated model; while the interclass correlation show that about 80.1 percent of the variance computed from the suitable fixed effects model was due to differences across panels.

5. Conclusion and Policy Recommendations

5.1. Conclusion

This paper estimated individual effects of distinct shares of population with access to electricity on economic growth in the SADC region during the period 2010-2020. Results indicate that an increase share of the total population with access to electricity had a significant but negative impact on economic growth during the period under review. Conversely, the shares of rural and urban populations with access to electricity had statistically significant and positive effects on economic growth. An increase in the share of rural population with access to electricity had a higher positive effect on economic growth than that of a rise in the share of the urban population.

These results are not consistent with findings reported by Mhaka et al. (2020) in case of Zimbabwe which indicate that access to electricity by the total population had a significant positive effect on economic growth. Nonetheless, results of this study relating to the effects of urban population and rural population with access to electricity on economic growth are contrary to those reported by Mhaka et al. (2020) which show that access to electricity by the urban population had a significant negative effect, while access to electricity by the rural population had a negative but insignificant effect on economic growth. Results of this study are somewhat similar to findings by Güler, Haykır & Oz (2022) which indicate that electricity consumption had a statistically significant negative impact on economic growth on a panel of thirty European countries between 2015Q1 and 2021Q3.

5.2. Policy Recommendations

Despite the similarities and differences of the results of this study to findings of other studies, it is clear in context of the SADC region that increases in proportions of rural and urban populations with access to electricity improves economic growth in the region. Based on these results, it can thus be inferred and concluded that improvements in access to electricity by populations in rural and urban populations boost economic growth in SADC. Consistent with the SDG goal 7, country governments and the region's relevant bodies responsible for monitoring the region's the energy agenda, like the ADC cluster on Infrastructure Development in Support of Regional Integration, should formulate and implement measures that improve access to electricity by both the rural and urban segments of the populations across the countries in the region.

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