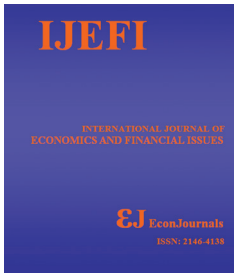

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Energy Consumption and Economic Growth: Evidence from SADC Countries

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ABSTRACT

This article examined the nexus between energy consumption and economic growth in selected Southern African Development Community (SADC) countries for the period 1980-2015. The study used both simple and multiple linear regression models to examine the relationship between the variables. The statistical results of the simple linear regression model between energy use and economic growth show a correlation coefficient of 0.060. This represents a weak positive correlation between the model variables. A coefficient of determination of 0.00476 depicts that energy use explains only 0.476% of the variability in the gross domestic product of countries investigated. The multiple linear regression model results show a multiple R of 0.3684, and an R^2 of 0.1358. This also depicts a weak positive correlation between the model variables. A coefficient of determination of 0.1358 means that energy use and electric power consumption accounts for only 13.58% of the values of the gross domestic product of selected Southern African Development Community countries and the balance is explained by the terms that are not specified in the model. This article is of value to policy makers in the region as well as the academia as it strives to close the gap in knowledge.

Keywords: Energy Use, Energy Consumption, Economic Growth, GDP, SADC
JEL Classifications: F43, O11, O13, O47, P48, Q43

1. INTRODUCTION

Globally the nexus between energy consumption and economic growth has attracted a lot of attention from both researchers and policy makers. Energy production and consumption are considered fundamental indicators of economic growth and development. Although few nations export energy, the majority of energy produced by developing countries is for domestic and industrial use. One of the major challenges facing developing countries is improving energy supply to satisfy the rising demand due to urbanization and industrialization without imposing unacceptable social, economic, and environmental damage.

Sustainable energy accessibility is critical for economic development. To foster economic growth in SADC, sustainable energy supply is vital for both industry and domestic use. An efficient and viable energy sector ensures economic stability through backward and forward linkages. Aged and dilapidated infrastructure makes countries experience significant energy shortages with negative consequences to the economy. Power importations is not sustainable for regional economic growth. Major suppliers of electricity in the region are South Africa and Mozambique although their supply is not sustainable given current power shortages in South Africa. To support economic growth and community prosperity, modern societies are becoming more dependent on secure energy supplies. This reliance is anticipated to increase as more effective and low-carbon power sources are created and implemented to aid in the decarbonisation of economies. A major challenge for nations is to maintain dependable and secure electricity services while attempting to rapidly decarbonize power systems. Stable and reasonably priced energy supplies are important to maintain and improve billions of

people`s lives as energy is the lifeblood of any modern economy (International Energy Agency [IEA], 2009). Trends in energy supply are economic, environmental and socially unsustainable. It is projected that energy demand will increase by 15% per annum, from 2007 to 2030 (IEA, 2009). As the energy demand increase, this is anticipated to have an increase in GDP (Mhaka et al., 2020). To achieve meaningful and sustainable economic growth there is need for massive replacement and rehabilitation of power infrastructure that have suffered dilapidation and vandalism. Energy needs in the region has greatly increased as a result of technological changes, population growth, economic growth and improved standards of living. IEA (2017) states that, 1.1 billion people do not have access to electricity the world over. Most SADC countries rely on hydroelectric power and thermal power (David, 2015). However, climate change has resulted in erratic rains which have negatively impacted power generation capacity in the region. Mhaka et al. (2020) argues that improving energy access to the people actually stimulates economy growth indirectly through consumption. Mhaka et al. (2020)`s findings complement findings by Khandker et al. (2013) and Van Gevelt (2014) who note that energy access to people increases economic growth. Increased energy production leads to increased production capacity in sectors such as mining, agriculture and financial services.

Though studies on the relationship between energy consumption and economic growth dates back to Kraft and Kraft's 1978 study, there is no consensus regarding the relationship between the two thereby creating a research gap that prompted this study. Research by Kouakon (2011) and Shahbaz and Lean (2012) show that energy use spurs GDP while Apergis and Payne (2011) found that economic growth drive electricity consumption. Chen et al. (2007), Hossain and Saeki (2011) and Tsaurai (2013) argue that there is no causality between economic growth and energy use. Major studies have only been done in developed countries with no or few studies done in SADC countries (Dat et al., 2020).

In this study we examined the following research objectives;

- The impact of energy consumption on economic growth in selected SADC countries.
- The relationship between energy consumption and economic growth in selected SADC countries, and
- The relationship between electric consumption, energy use and economic growth in SADC countries.

The research findings will be of significance to regional policy makers and researchers as it adds to the body of knowledge. The rest of the article will be as follows, literature review followed by research methodology then discussion of results and finally conclusion and recommendations.

2. LITERATURE REVIEW

Magazzino et al. (2021) argue that because energy use is the major driver of economic growth and development, it has attracted much attention in the recent past. Existing literature has examined the impact of energy use on GDP in various countries the world over with few or no studies targeting SADC countries (Bekun et al., 2019; Sarkodie et al., 2020; Ali et al., 2020; Etokakpan et al., 2020; Adedoyin et al., 2020; and Magazzino et al., 2021; Abdibekov et al., 2023; Khan and Khan, 2024; Mohamud and Mohamud, 2023; Nor et al., 2024; Susilo et al., 2024; Gunarto et al., 2024; Ismail et al., 2024). However, there is no consensus on the causality between economic growth and energy consumption in literature. Table 1 below shows empirical summary of studies on between energy use and economic growth. Lin and Zhou (2023) argue that GDP target formulation is a critical component of development that has effects on energy use. Abbasi et al. (2021) and Caglar et al. (2022) found that energy use increases GDP. A study by Hao et al. (2020) on China from 1995 to 2014 shows a two way causality between energy use and GDP. Lin and Zhou (2023) found that industrial structure and urbanization development affect energy consumption and economic growth.

2.1. Energy Consumption and Economic Growth

Four hypotheses has been formulated and tested in different countries on the causality of energy use and GDP. Alkhars et al. (2020) noted that the nexus between energy use and GDP is explained by four hypotheses which are the growth, conversation, feedback and neutrality. These hypotheses are in line with findings by Mutumba et al. (2021) `s survey of literature on economic growth and energy consumption for the period 1974 to 2021.

Growth hypothesis proponents note that energy use induces GDP directly and indirectly through complementing labour and capital (Zalle, 2019 and Titalessy, 2021). Hasanov et al. (2017) states that energy use influences GDP. Mutumba et al. (2021) contend that conservative energy policies can negatively impact GDP through reduced energy use.

The conservative hypothesis suggests that energy policies aimed at reducing energy use could potentially boost economic growth (Aydin, 2019 and Nasreen et al., 2020). There is uni-directional causality from economic growth to energy consumption (Mutumba et al., 2021). This notion is in line with the findings by Minh and Van (2023) who examined the relationship between energy consumption and economic growth in Vietman from 1995 to 2019 using ARDL methods. Rahaman et al. (2023) also studied South and East Asian countries using ARDL. Odhiambo (2023) whose study focussed on South Africa notes that the country can still pursue energy conservation policies and renewable energy exploration without wholly compromising its comprehensive economic growth. The conversation believes that economic growth influence energy consumption (Al-Mulali et al., 2019). This is contrary to the growth hypothesis.

Feedback hypothesis alludes to interdependent relationship that exists between energy use and GDP (Kahia et al., 2019 and Zafar et al., 2019). This relationship results in bidirectional causality. Energy efficiency policy should positively affect the overall health of the economy (Mutumba et al., 2021). This is also in line with findings by Zou and Chan (2023)`s study on China for the period 1965 to 2016. The relationship in the feedback hypothesis is bidirectional (Mohammadi and Parvaresh, 2014 and Ali-Mulali and Sab, 2018).

Table 1: Empirical studies on energy consumption and economic growth

Period	Author	Title	Method	Findings
1980-2018	Muazu et al. (2023)	"Does renewable energy consumption promote economic growth? An empirical analysis of panel based on African countries."	Panel threshold regression model	Neutrality hypothesis holds.
	Alqaralleh and Hatemi (2023)	"Revisiting the effects of renewable and non-renewable energy consumption on economic growth."	Asymmetric quantile based	Feedback hypothesis (that is feedback between the two variables).
2001-2009	Lahrech and Abu-Hijleh (2023)	"The impact of global renewable energy demand on economic growth evidence from GC countries."	Panel regression model	Conservative hypothesis holds between the variables.
1980-2016	Minh and Ngoc (2023)	"Spatial relationship between financial development, energy consumption and economic growth in emerging markets."	Spatial error model and Autoregressive model	Conservative hypothesis holds between the variables.
1981-2021	Quang-Bal et al. (2023)	"Financial development, energy consumption and economic growth in the Asian countries."	GMM and Var	Feedback hypothesis (that is feedback between the two variables).
1990-2015	Mutumba et al. (2022)	"Renewable and non –renewable energy consumption and economic growth in Uganda."	Regressive distributed lag and Granger causality	Growth hypothesis holds between the variables.
1975-2017	Aydin et al. (2022)	"Does energy intensity matter in the nexus between energy consumption and economic growth?"	PSTR Model	Growth hypothesis holds between the variables.
1989-2019	Safitri et al. (2022)	"The role of energy consumption and economic growth on the ecological environment in Asian countries."	ARDL	Feedback hypothesis (that is feedback between the two variables).
1980-2016	Tuna et al. (2022)	"The relationship between energy consumption and economic growth in G7 countries."	Causality asymmetric	Feedback hypothesis (that is feedback between the two variables).
1992-2018	Mhaka et al. (2020)	"Impact of rural and urban electricity access on economic growth in Zimbabwe."	Dynamic ordinary least square (DOLS)	Energy consumption stimulates economic growth.
1971-2015	Sunde (2020)	"Energy consumption and economic growth modelling in SADC countries."	Var granger causality	There is no causality effect between the two.
2000-2019	Dat et al. (2020)	"Energy Consumption and Economic Growth in Indonesia."	Autoregressive distributed lag co-integration	Energy consumption stimulates economic growth.
1980-2016	Nkroro et al. (2019)	"Energy consumption and economic growth in Nigeria."	Ordinary least square	Energy consumption stimulates economic growth.
1991-2015	Shahbaz et al. (2018)	"The energy consumption and economic growth nexus in top ten energy consuming countries."	Quantile on Quantile	Energy consumption stimulates economic growth.
1980-2012	Kahia et al. (2017)	"Renewable and non-renewable energy use-economic growth nexus."	Cobb-Douglas	Economic growth causes energy consumption.
1990-2012	Inglesi-lotz (2016)	"The impact of renewable energy consumptions to economic growth."	Cobb-Douglass	Economic growth causes energy consumption.
1971-2012	Zeshan and Ahmed (2013)	"Energy consumption and economic growth in Pakistan."	Structural vector auto regression (SVAR)	Economic growth causes energy consumption.
1980-2011	Tsaurai (2013)	"Is there a relationship between electricity consumption and economic growth in Zimbabwe?"	Bi-Variate causality	There is no causality effect between the two.
1970-2006	Erdal et al. (2008)	"The causality between energy consumption and economic growth in Turkey."	Granger causality co-integration	Feedback hypothesis (that is feedback between the two variables).
	Yoo (2006)	"The causal relationship between electricity consumptions and economic growth in ASEAN countries."	Time series	There is no causality effect between the two.

Neutrality hypothesis is supported by Sunde (2020) and Belal et al. (2021) among others. Under this hypothesis, energy consumption is a small component of an overall economic output hence little or no impact on GDP. There is an absence of causal relationship between energy use and GDP. Kim and Park (2022) in support of Azam et al. (2015)`s found non-linearity in South Korea. A study by Laszlo (2023) in EU countries for 2010 to 2019 shows no robust correlation between GDP and energy use. The neutrality hypothesis believes that there is no relationship between energy use and GDP (Chang et al., 2015).

Energy accessibility and use play an important role in economic development (Minh and Ngoc, 2023). More energy is required to accelerate capital accumulation and sustain economic growth (Aydin et al., 2022). Therefore, 29% of previous studies supports the growth hypothesis, 27% supports the feedback hypothesis, 23% supports the conversation, while 21% supports the Neutrality hypothesis (Minh and Ngoc, 2023).

3. RESEARCH METHODOLOGY

This study examines the relationship between electric consumption and energy use on GDP in SADC countries from 1980-2015. In this study we used a linear regression analysis model (LRAM) that involves data analytical techniques to assess the impact of electric consumption and energy use on SADC countries' GDPs over the period under review. The study used both simple and multiple models to examine the impact of electric consumption and energy use on GDP of five countries namely Botswana, Mozambique, South Africa, Zambia, and Zimbabwe. A linear regression model was applicable to ordinary paired data. MLR models have been used previously especially those based on, for instance, analysis of variance (ANOVA). These have provide valuable in recent times to test relationships in panel and time-series data.

Both simple and multiple linear regression analyses (MLRA) enable researchers to examine the strength of the linear relationship between an outcome (dependent variable) and a family of input (independent) variables. MLRA can also be used to assess the significance of each of the inputs to the postulated model relationship, as well as the effects of these predictors on other predictors that are statistically eliminated from the model. In other words MLR requires at least two independent variables to differentiate it from simple linear regression modelling. The independent variables for MLRA can be nominal, ordinal, ratio or interval level variables. A rule of thumb for the sample size is 20 scores for the independent variable to make the results drawn from regression analysis generalizable.

The major advantages of MLR are that it leads to more precise and accurate understanding of the association of each individual factor with the dependent or output variable. The major conditions required for linear regression to be application are linearity, homoscedasticity, independence and normality. This means that the relationship between X (input) and the mean of Y (output) is linear and the variance of the residuals is the same for any value assumed by X (homoscedasticity). On the other hand it is also assumed that variable observations are independent of each other and that for any fixed independent variable, X, Y is always normally distributed.

As a result, multiple linear regression is an extension of basic linear regression, which is used to predict the value of an output variable using the values of two or more independent variables. This method extends simple linear regression by predicting a variable`s value based on the values of two or more additional variables. The variable to forecast is known as the target, criterion, output, or dependent variable. The hypothesis connecting the output and independent variables for the study under consideration is:

Null hypothesis (H_0): Energy Consumption has no impact on GDP.

Alternative hypothesis (H_1): Energy Consumption has impact on GDP.

4. DISCUSSION OF RESULTS

The results of the study are presented, analysed based on the linear regression analysis models (LRAM), both simple and multiple linear regression models below:

4.1. Simple Linear Regression Model Results

The results of the simple linear regression model graphed below suggest that the residuals of the dependent variable, GDPs are positive and negative, clustered between −20 and 20 kg per capita and significant at the 1% level of significance test. Figure 1 shows that the energy used ranged between 750 and 1 000 kWh and is not very significant to influence GDP in all SADC countries in the 44 year period under review.

Under the line of best fit drawn Figure 1, GDP annual growth rate is between −50% and 50% and wider than the predicted GDP rates relative to the energy used in kWh. On the other hand, the constant term connecting energy use per capita has positive and statistically significant and insignificant relationships respectively with the gross domestic product (GDP) annual and predicted growth rates in Zimbabwe in the period under review.

The statistical results of the simple linear regression model between energy use and GDP show a correlation coefficient of 0.060 (Table 2). This figure represents a weak positive correlation between the two model variables. A coefficient of determination of 0.00476 depicts that energy use explains only 0.476% of the variability in the GDPs of countries investigated and the balance is accounted for by terms in the error or noise term. The intercept of the fitted energy use model is 8.679, which is significant in its contribution to the GDP of the country (Table 2). We also performed an ANOVA test on the model connecting energy use and GDP, and results show that the variables have a strong negative relationship at 1% level of significance.

4.2. Multiple Linear Regression Model Results

We also ran a LRAM between GDP as dependent variable and both electric power consumption and energy use as independent variables. The residual results obtained show that energy use (kg of oil equivalent per capita) ranged between 750 and 1 000 from the initial range of 600-1 000 under the simple regression model illustrated above. The major findings of the study on the impact

Table 2: Linear regression summary output

Regression Statistics								
Multiple R	0.0607							
R^2	0.0048							
Adj. R^2	−0.0200							
Std. Error	8.2884							
Observations	220							
ANOVA								
	Df	**SS**	**MS**	**F**	**Significance F**			
Regression	2	18.9868	18.9868	0.2574	0.7486			
Residual	217	17225.848	78.6573					
Total	219	17244.936						
	Coefficients	**Std.Error**	**T Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	−0.6409	8.679	−0.1615	0.9673	−16.9624	18.5456	−17.9646	15.4578
Energy use	0.0143	0.08774	0.4778	0.7275	−0.03871	0.0485	−0.0274	0.0379

Figure 1: Line fit plot (Energy use, kg of oil equivalent per capita)

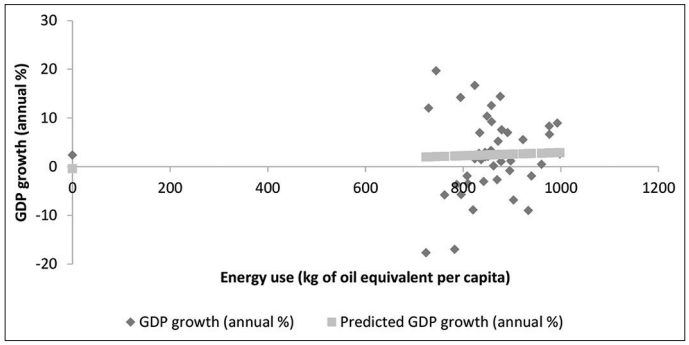


Figure 2: Line of best fit plot (Electric power consumption, kWh per capita)

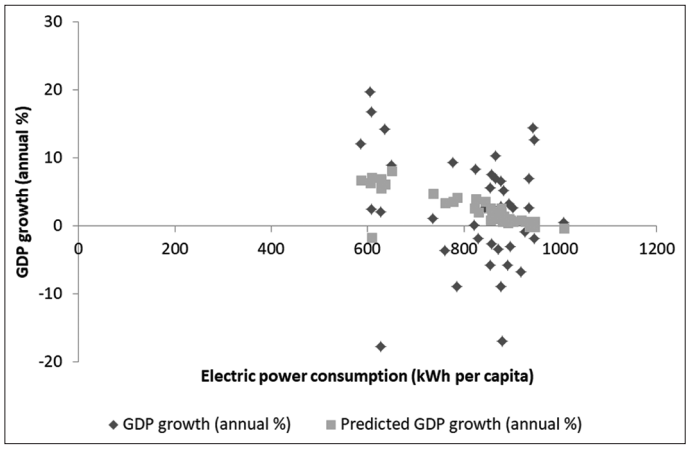
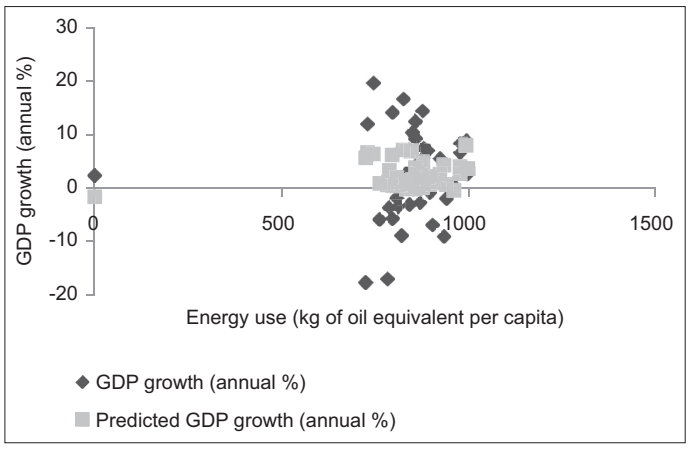


Figure 3: Line of fit plot (Energy use, kg of oil equivalent per capita)



of energy use and electric power consumption on annual growth rates of GDPs of countries realised above are not in agreement with the works by many previous scholars such as Sunde (2020). The scholars used evidence from 1977 to 2020 to determine the impact of energy use and electric power consumption on GDPs of SADC counttries. They discovered that energy use and electric power consumption are important variables because they promote economic growth and reduce poverty in the communities and societies at large.

However, according to Tsauri (2013), Maune (2019), Maune and Matanda (2019), Maune (2021), economic growth is determined by many factors such as human capital development, foreign direct investment, governance, trade services, financial and market development and no mention of energy use and electric consumption is made. Shahbaz et al. (2018) carried out a research on the impact of energy consumption on economic growth and conclude that these variables' impact on GDP is weakly positive. A research by Simelyte and Dudzeviciute (2017) state that trade, capital and labour are critical in an economy because they improve production, productivity and in turn access of citizens to goods and services needed in meeting their basic necessities of life and wants and hence accelerate economic growth of a country towards sustainability.

The lines of best fit connecting the GDPs to the two independent variables are as illustrated in figure 2 and 3 above The impact of electric power on the countries' annual GDP growth rates (%) is slightly upward sloping while that of the predicted GDP is horizontal and in three stages and concentrated between 580 and 1000. On the other hand the impact of energy use on the countries' GDPs shows a wider plot for the annual growth rate (%) than the predicted annual rate of growth (%). In reality the predicted GDP annual rates are more consistent and reliable than the observed growth rates. This demonstrates that MLRAM smoothens the variability of both independent variables to give results that are free from shocks and all other random (irregular) variables that have short term impact on the GDPs of countries in the period of 44 years under review.

Table 3: Multiple linear regression output

Regression Statistics							
Multiple R	0.3684						
R^2	0.1358						
Adj. R^2	0.0682						
Std. Error	8.2894						
Observations	220						
ANOVA							
	df	**MS**	**F**	**Sig. F**			
Regression	2	136.9832	1.0616	0.16876			
Residual	217	84.7836					
Total	219						
	Coefficients	**T Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	16.2513	1.3754	0.2268	−7.3436	36.4563	−7.1628	34.4789
EPC	−0.0328	−1.8497	0.0746	−0.0629	0.01336	−0.0473	0.01718
ENU	0.02608	1.6893	0.2934	−0.0175	0.02904	−0.0465	0.03946

EPC: Electric power consumption, EU: Energy use

Figure 4: Residual plot (Electric power consumption, kWh per capita)

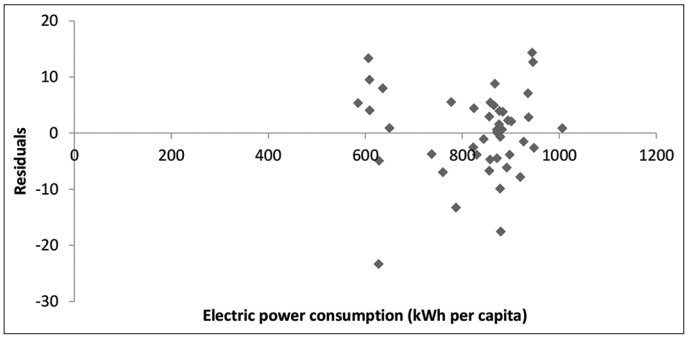


Figure 5: Residual plot (Energy use, kg of oil equivalent per capita)

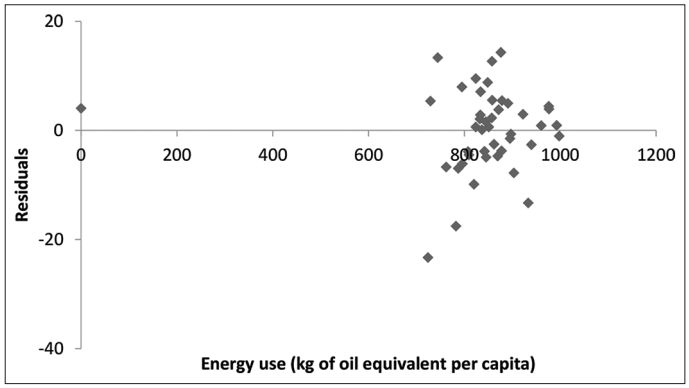
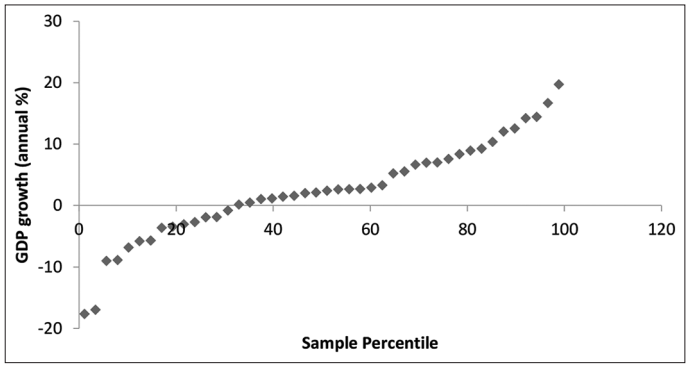


Figure 6: Normal probability plot



The statistical results of the MLRAM between the combined contribution of energy use and electric power consumption to the GDP as dependent variable demonstrates that the correlation coefficient is 0.3684 (Table 3). This figure of 36.84% depicts a weak positive correlation between the two model variables (Table 3). A coefficient of determination of 0.1358 means that energy use and electric power consumption accounts for only 13.58% of the values of the GDPs of all SADC countries and the balances are explained by the terms in the random term, which are not specified in the model (Table 3). The intercept of the fitted model is 16.2513, which is significant in its contribution to the countries' GDP. However the F value of the ANOVA test between countries' GDPs and energy use and electric power consumption was 0.10616, which means the relationship is not significant at 1% level (Table 3).

The residual results under the MLRAM (Figures 4 and 5) demonstrate that inclusion of energy power consumption and energy use in kg per capita translates into more energy use in predicting the countries' GDPs. However, the countries' GDPs did not respond significantly to the two independent variables, implying that there was significant wastage of the two resources in the period under investigation.

The normal probability plot from the MLRAM (Figure 6) demonstrates a direct relationship between the sample percentiles and annual growth rates in the countries' GDPs over the period under investigation. Although the countries' GDPs slope upwards (Figure 6) the research cannot out rightly determine the composition of the goods and services leading to the upward sloping trend based on the sample data of the model's independent variables. Overall the GDPs' growth rates remain contained between -50% and 50% for the sample period of 44 years whose energy use and consumption are used in the validation of the regression model for predicting the countries' GDP annual growth rates.

5. CONCLUSIONS AND RECOMMENDATIONS

In line with the findings of this study, we infer that the connection between GDP, energy use and consumption is positive but relatively negligible at the 1% level of significance. The study further

concludes that the investigated countries are investing huge sums of money and other resources in energy production and consumption, which expenditures are not proportionately the realised rates of growth in their GDPs in the period under review. We also conclude that the medium to long–run energy use and consumption made in the economies are positive and negative and clustered horizontally over the period under consideration. Most SADC countries' economic growth remain very low or insignificant over the 44 years period despite massive investment in energy production and electric consumption for growth and development of the economies.

The study further concludes that output realised from investment in energy production, use and electric consumption is not commensurate with the investments made by governments of SADC countries in sectors such as industry and commerce and agriculture. This is another research topic for another day to determine why the countries' GDPs are not directly related to the levels of resources investment in energy, let alone the continuous deterioration in living standards of people, worsening inflation and unemployment rates particularly in countries such as Zimbabwe of late. The study also concludes that the constant term of the MLRAM has a positive and statistically significant link with the gross domestic products (GDPs) in SADC nations over the review period. This conclusion implies that the terms in the error component have more contribution to the dependent variable than the two independent variables included in the model.

The article concludes by advocating that SADC governments, particularly Zimbabwe`s, avoid politicizing economic variables like currency difficulties, energy provisioning, and consumption in their businesses in order to move toward sustainability. Zimbabwe stands significantly outstanding from most member countries as it is unique in terms of having a continuously growing GDP due to regular investment in ammunition against the background of acute shortage of electricity, a very weak currency not in the basket of currencies, three digits inflation rate and more than 90% unemployment rate. By delivering adequate and dependable energy at all times, the majority of SADC nations are able to strike a balance between their demand and supply strategies, attracting both foreign and domestic investments necessary for sustainable GDP growth.

Therefore, SADC countries should move away from monopoly energy generation and liberalise the provisioning to attract private investors into the industry and create employment at the same time for the citizens. This will not only improve the GDP levels but also impact positively on living standards of people, foreign currency flows and infrastructure provisioning and development. Finally, by democratisation and liberalisation of public institutions, political and the financial systems, SADC countries can achieve nationalisation, independence from developed countries, self-reliance and sufficiency, increased productivity and growth towards sustainable development measured in terms of attainment of modern infrastructure and improved living standards of their citizens.

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