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Unlocking Zambia's Power Potential: Exploring the Economic Drivers of Electricity Exportation

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Abstract

This study explores the economic drivers of electricity exportation in Zambia, focusing on both short-run and long-run dynamics. Using an Autoregressive Distributed Lag (ARDL) model, we analyse the relationships between electricity export and exchange rate, electricity generation, installed capacity, and electricity consumption per capita between 1990 and 2020. In the short run, findings reveal that electricity export, electricity generation, and installed capacity significantly impact export levels. Specifically, decreases in electricity exports are associated with reduced export levels while an increases in electricity generation and installed capacity lead to higher exportation. However, the exchange rate and electricity consumption per capita do not exhibit significant short-run effects on exportation. In the long run, our analysis demonstrates the enduring importance of several factors in driving electricity exportation. A depreciating exchange rate, increased electricity generation, and greater installed capacity positively influence export levels. Conversely, higher electricity consumption per capita is associated with decreased exportation over extended periods. Our study contributes to the understanding of the complex dynamics shaping Zambia's electricity export sector, providing insights valuable for policymakers, industry stakeholders, and investors.

Keywords: Electricity export, Electricity generation, Exchange rate, Zambia

1. Introduction

1.1 Background

Zambia, situated in Southern Africa, is rich in natural resources, notably abundant hydroelectric potential. Since its independence in 1964, the country has prioritized the development of its energy infrastructure, primarily relying on hydroelectric power generation (Ahmed, et al., 2023). However, despite these resources, Zambia grapples with challenges in meeting its domestic energy demands due to rapid population growth, urbanization, and industrialization (Winston, et al., 2021). The country's hydroelectric dominance positions it as a potential energy hub within the Southern African region. With borders shared with eight neighbouring nations, Zambia stands strategically poised for energy trade and regional cooperation, evident through initiatives like the Southern African Power Pool (SAPP) (Spalding-Fecher, 2018). Leveraging its surplus electricity production can not only boost Zambia's economy but also contribute to regional energy security and integration.

Economically, exploring electricity exportation offers Zambia numerous benefits. Firstly, it presents a

pathway for revenue generation and foreign exchange earnings, diversifying the country's income streams away from traditional commodities. Moreover, it aligns with broader economic development goals by attracting foreign investment in energy infrastructure and related sectors, thus fostering job creation and industrial growth (African Development Bank Group, 2023). A reliable and affordable electricity supply is crucial for enhancing the competitiveness of Zambian industries, particularly in mining, manufacturing, and agriculture. However, while the economic advantages are compelling, it is essential to consider sustainability and environmental implications. Hydropower projects, though renewable, can have significant ecological impacts, such as habitat disruption and altered river ecosystems. Additionally, the vulnerability of hydropower to climate change underscores the need for diversifying Zambia's energy mix and investing in resilient infrastructure.

Balancing economic development with environmental sustainability requires robust policy frameworks and stakeholder engagement. Prioritizing responsible resource management, incorporating environmental impact assessments, biodiversity conservation measures, and community participation into energy development strategies are crucial steps.

1.2 Problem Statement

The problem statement revolves around Zambia's endeavour to unlock its power potential through electricity exportation while simultaneously addressing domestic energy challenges, promoting economic growth, and ensuring environmental sustainability. This entails striking a delicate balance between the economic imperatives of exporting electricity, the need for reliable and affordable energy domestically, and the environmental impacts associated with hydropower development. One of the primary challenges facing Zambia is the inability to meet its domestic energy demands due to rapid population growth, urbanization, and industrialization (Zulu & Mumba, 2018; Mwila & Johnson, 2017). These factors contribute to energy deficits, hindering broader economic development and posing constraints on the country's industrialization ambitions. Consequently, there is a pressing need to address these deficits while exploring the potential for electricity exportation to capitalize on the country's hydropower resources.

Moreover, exporting electricity presents Zambia with significant economic opportunities. It offers the potential to generate revenue, diversify income streams, attract foreign investment, create jobs, and enhance the competitiveness of its industries (Mhango & Mwanza, 2023; Kaunda, 2013). However, realizing these economic benefits requires strategic planning, investment in energy infrastructure, and effective policy frameworks. Despite the economic incentives, Zambia must also consider environmental sustainability. Hydropower development, while renewable, can have adverse ecological impacts, including habitat disruption, deforestation, and altered river ecosystems. Thus, the country must balance economic development with environmental conservation, incorporating measures to mitigate these impacts and ensure the long-term sustainability of its energy sector.

Furthermore, Zambia's strategic location within the Southern African region presents opportunities for energy trade and regional cooperation through initiatives like the Southern African Power Pool (SAPP). However, realizing the potential of electricity exportation requires collaboration with neighbouring countries and alignment with regional energy objectives. Effective policy frameworks and governance structures are essential for guiding Zambia's energy development strategies. This includes promoting transparency, accountability, and stakeholder participation, ensuring that economic, social, and environmental considerations are adequately addressed. Overall, the problem statement highlights the multifaceted challenges and opportunities associated with unlocking Zambia's power potential and underscores the need for a comprehensive and integrated approach to address them.

2. Literature Review

2.1 Theoretical review

In this section, we shall summarize some of the theories relating to international trade of products.

Comparative advantage

In the theoretical review of "Unlocking Zambia's Power Potential: Exploring the Economic Drivers of Electricity Exportation," the Comparative Advantage Theory emerges as a pivotal framework for understanding the dynamics of international trade in the context of electricity exportation. Developed by David Ricardo in the early 19th century, this theory asserts that countries should specialize in the production

of goods and services in which they have a comparative advantage, and then trade with other nations to maximize overall welfare (Salvatore, 2020).

Central to the Comparative Advantage Theory is the concept of opportunity cost. In the context of electricity exportation, Zambia must evaluate the resources and capabilities it possesses relative to other potential exporters. This involves considering not only the direct costs of electricity production but also the opportunity costs of allocating resources to this sector rather than to alternative uses such as agriculture, mining, or manufacturing. Zambia's comparative advantage in electricity production may stem from various factors, including abundant natural resources like water for hydropower generation, favourable climatic conditions for renewable energy sources, or a skilled workforce in the energy sector. By identifying and leveraging these inherent strengths, Zambia can enhance its competitiveness in the global electricity market.

Furthermore, the theory emphasizes the importance of trade as a mechanism for mutual benefit (Krugman, et al., Pearson). By specializing in electricity production and exporting surplus electricity to neighbouring countries or even farther afield, Zambia can not only generate revenue but also foster regional integration and cooperation. Through trade, countries can capitalize on their respective strengths, mitigate inefficiencies, and achieve higher levels of economic growth and development. However, it's essential to acknowledge the challenges and complexities inherent in implementing the Comparative Advantage Theory in the context of electricity exportation. These may include infrastructural constraints, regulatory barriers, geopolitical considerations, and market volatility. Addressing these challenges requires a holistic approach that integrates policy reforms, infrastructure investment, technological innovation, and strategic partnerships.

Heckscher-Ohlin Theory

In addition to the Comparative Advantage Theory, the Heckscher-Ohlin (H-O) Theory constitutes another essential framework in understanding the dynamics of international trade, particularly in the context of Zambia's electricity exportation potential. Developed by Swedish economists Eli Heckscher and Bertil Ohlin in the early 20th century, this theory builds upon the principles of comparative advantage but introduces the role of factor endowments in determining trade patterns (Baldwin, Harvard University Press.).

At the heart of the H-O Theory lies the notion that countries will export goods that intensively use their abundant factors of production and import goods that utilize their scarce factors (Caves, et al., 2017). In the context of electricity exportation, this theory prompts an examination of Zambia's factor endowments, particularly in relation to the production of electricity. Zambia's factor endowments encompass various resources and inputs crucial for electricity generation, including natural resources such as water, minerals for thermal power generation, and human capital for the development and operation of energy infrastructure. The H-O Theory suggests that if Zambia possesses abundant water resources suitable for hydropower generation, it may specialize in electricity production using this method and export electricity to countries where hydropower resources are scarce.

Moreover, the H-O Theory emphasizes the role of trade in equalizing factor prices between countries. In the context of electricity exportation, trade allows Zambia to capitalize on its abundant factor—whether it be water, mineral resources, or skilled labor—in electricity production, thereby enhancing its overall welfare. Additionally, by exporting electricity, Zambia can earn revenue to invest in other sectors or to further develop its factor endowments, contributing to long-term economic growth. However, the applicability of the H-O Theory to Zambia's electricity exportation potential is subject to various considerations and challenges. These may include technological constraints, infrastructure limitations, regulatory frameworks, and geopolitical factors influencing trade relations with neighbouring countries and beyond.

2.2 Empirical review

Historically, the drivers of energy exports were primarily influenced by consumption patterns, both domestically and internationally. (Fan, et al., 2023) Explored the trends and drivers of energy export dependency in 40 major countries from 2000 to 2019 through a decomposition approach. The study found that energy prices and energy export importance are the key drivers of the increase in energy export dependency in OECD countries, while technological progress can effectively reduce the energy export dependency of non-OECD countries by decreasing energy intensity.

In a similar study, Jayalath and Wijayatunga (2014) did an assessment of the geographic determinants of electricity exportations. The research mainly focused in Africa and the findings were that the availability of

natural resources played a major role in electricity exportations. This was evident from South Africa and Botswana which are rich with coal and more than 90% of their electricity are produced by coal. Tanzania, rich with natural gas relies its electricity exportation on gas and Zambia with more than 95% of its electricity as hydropower, also rely heavily on the availability of rainfall.

Chris and Risako had conducted a research on the economic determinants of power imports and exports in Taiwan. The specific research objectives were that electricity exportations depends on; the exchange rate, generation capacity and the available technology. The above factors were also found to explicitly determine electricity importations. The findings were that all the research objectives were achieved. The appreciation of their currency reduced electricity exported and its depreciation stimulates electricity exported and vice versa for imports. And a positive relationship was found between the rate of power generation and power exported. An advancement in technology and increased capital productivity and therefore, more and more power was generated and exported at less costs (Chris, Charlotte and Risako, 2009).

Benson and Clay (2012) entitled 'the extent of electricity exportation in Africa' had the following findings concerning factors leading to electricity exportations in specified African countries. Domestic demand was negatively related to electricity exportations. However, the coefficient of correlation of electricity exportation and domestic consumption was high in emerging countries such as South Africa and low in poorer countries such as Malawi. The nation's government type; such as capitalist, socialist, democracy, republican... also played a major role in determining how much electricity was exported. Socialist countries such as Mozambique exported less while on the other hand, democratic countries like Congo DR and Zimbabwe had a steeper exportation supply function of electricity (the exported more electricity). The research went on that, a given year whether election year or not mattered as far as electricity exportations are concerned. In Zambia for example, the rate of electricity exported were less in 2011, 2006 and other election years.

Lwao conducted a research entitled 'the relationship between domestic inflation and electricity exportation'. The research revealed a negative relationship between inflation and electricity exported. ZESCO finds it more profitable to export more of its power to other nations if the domestic currency rises in value in relation to other currencies (Lwao, 2009). The researcher however, did not take into account the effect of generated electricity or imported electricity on electricity exported. It is this and other mentioned gaps that this research will seek to fill up.

Chisela (2008) had conducted a study using 27 yearly data from 1980 to 2007 on the relationship between electricity generated and exported. The findings were as follows: a strong positive correlation ($r^2 = 0.726$) was observed, indicating that electricity exported in Zambia at any point in time depends on how much is generated at that time. And a positive correlation was also observed between the amount of rainfall experienced and the amount of electricity generated. The researcher however, did not take into account the effect of imported electricity and other factors on electricity exported. Our research will seek to fill up that gap. Energy has been shown to be equally as important in production as other factors such as labour, land and capital. This was evident from the research entitled: "The relationship between economic growth and electrical power demand". The specific objective of this study were; to establish the impact of power rationing on economic growth, and to establish the impact of power rationing on investment opportunities. The findings of this study, done by Ferguson were that there was a strong correlation between electricity consumption and GDP per capita. And showed that there is a stronger correlation between electricity usage and wealth creation. The study also shows that in wealthy countries, an increase in wealth over time correlates with an increasing proportion of energy used in the form of electricity (Ferguson et al, 2007). This study however, only focused on how electricity rationing affects economic growth and did not tackle on factors that are leading to power being rationed which includes electricity exportation.

Methodology

The study used secondary time series covering a period of study, that is, from 1990 to 2020. The data was collected from World Bank online database and ZAMSTATs. The study used secondary time series data and the variables used in this study were; Electricity export (KwH), electricity installed capacity, exchange rates, Gross Domestic Product and amount of rainfall.

Variable description

i. Electricity Export

Electricity export, measured in billion kilowatt-hours (billion kWh), represents the total amount of electricity generated domestically and sold to foreign markets over a specific period. This variable serves as a crucial indicator of a country's ability to leverage its electricity surplus for economic gains through international trade.

ii. Electricity installed capacity

Electricity installed capacity refers to the maximum amount of electricity that a country's power generation infrastructure can produce under optimal conditions. It is typically measured in kilowatts (kW) or megawatts (MW) and represents the total capacity of power plants, including both operational and standby facilities. In Zambia, installed capacity reflects the nation's ability to meet domestic electricity demand and potentially export surplus electricity to neighboring countries.

iii. Exchange rate

Exchange rates represent the value of one currency relative to another and play a significant role in shaping a country's international trade dynamics, including electricity exports. Fluctuations in exchange rates can impact the competitiveness of exported goods and services, including electricity, by affecting their prices in foreign markets.

iv. Electricity consumption per capita

Electricity consumption per capita refers to the average amount of electricity consumed by an individual within a given population over a specific period, typically measured in kilowatt-hours (kWh) per person. This metric provides valuable insights into the energy consumption patterns and living standards of a country's population. In the Zambian context, electricity consumption per capita reflects the level of access to electricity, the degree of electrification, and the energy usage habits of the populace. Analyzing electricity consumption per capita can offer valuable insights into various socioeconomic factors, including urbanization, industrialization, income levels, and technological advancements.

v. Electricity Generation

Electricity generation, measured in gigawatt-hours (GWh), represents the total amount of electricity produced by power plants within a specific timeframe. It serves as a fundamental indicator of a country's capacity to meet domestic energy demand and support various economic activities. In Zambia, electricity generation primarily relies on hydropower, with significant contributions from other renewable and non-renewable sources.

Econometric Approach and Estimation Procedure

Pesaran & Shin (1995) and Pesaran et al. (1996) proposed an Autoregressive Distributed Lag (ARDL) model approach for estimation in cases where the variables are integrated of order zero, one or a combination of both. According to Pesaran (2001), when faced with such situations, the application of the ARDL in the modeling for cointegration will give realistic and efficient estimation.

The general *ARDL* ($p, q_1, q_2, \dots, q_k$) model specification by pesaran (2001) is;

$$\Phi(L, p)y_t = \sum_{i=1}^k \beta_i(L, q_i)x_i + \vartheta w_t + \varepsilon_t \quad (1)$$

Where

$$\Phi(L, p) = 1 - \Phi_1 L - \Phi_2 L^2 - \dots - \Phi_p L^p$$

$$\beta(L, p) = 1 - \beta_1 L - \beta_2 L^2 - \dots - \beta_q L^q \quad \text{for } i=1,2,3,\dots,k, \varepsilon_t \sim ii(0, \delta^2)$$

L is the lag operator implying $L^0 y_t = y_t$, $L^1 y_t = y_{t-1}$ and w_t is $n \times 1$ is a deterministic vector of the intercept, time trends or any exogenous variable with the lags $p=0,1,2,\dots, m$, $i=1,2,\dots,k$. The maximum lag order, m , is determined empirically by information criterions.

Subtracting y_{t-1} from sides and rearranging, equation 1 can be reparemeterized into as ECM given as;

$$\Delta y_t = \beta_0 \Delta x_t - \pi ECT_{t-1} + \mu_t \quad (2)$$

Where β_0 Coefficient captures the short-run dynamics of the model while the $ECT = \varphi_{t-1} = y_{t-1} - \alpha - \beta_1 x_{t-1}$ and the coefficient α and β_1 are long run coefficients. π in equation 2 is the adjustment coefficient which tells us how much of the adjustment to equilibrium takes place in each period.

The study thus ran the following ARDL model with the variables of interest.

$$\Delta \ln EE_t = \alpha_0 + \sum_{i=1}^k \alpha_{2i} \ln EE_{t-i} + \sum_{i=0}^k \alpha_{2i} \Delta \ln EG_{t-i} + \sum_{i=0}^k \alpha_{3i} \Delta \ln LL_{t-i} + \sum_{i=0}^k \alpha_{4i} \ln FXR_{t-i} + \sum_{i=0}^k \alpha_{5i} \ln EC_{t-i} + \varphi ECT_{t-1} + \mu_t \quad (3)$$

μ_t is the Gaussian error or residue term satisfying the econometric assumptions of constant variance and zero mean and k is the number of lags to be determined empirically.

Augmented Dickey Fuller Test

Dickey and Fuller (1979 & 1981) devised a statistical procedure to formally test for non-stationarity of a time series. The general form of the test is estimated as;

$$\Delta Y_t = \vartheta_0 + \vartheta_1 Y_{t-1} + \sum_{i=1}^n \mu_i \Delta Y_{t-i} + \delta t + \varepsilon_t \quad (3)$$

Where Y_t is the time series, t is the linear trend, Δ is the difference operator and ε_t is the random error term. The ADF test also includes the extra lagged terms ($=Y_{t-i}$) of the dependent variable in order to eliminate autocorrelation in the test equation. The rejection of the null hypothesis implies the variable is stationary.

Phillips Perron Test

The regression for the PP test is similar to unit root test by Dickey and fuller.

$$\Delta Y_t = \lambda_0 + \lambda_1 Y_{t-1} + \varepsilon_t$$

Unlike the ADF test that corrects for higher order autocorrelation by adding differenced lags, the Phillips-Perron (PP) test makes a correction to the t -statistic of the coefficient from the AR(1) regression to account for the serial correlation in ε_t (Phillips & Perron, 1988).

Optimal lag selection

The optimal lag selection was determined using the Akaike information criterion (AIC) after the model was subjected to the unrestricted VAR estimations.

Co-integration Tests

The bounds cointegration test was used to test for the long run relationship of the variables. The existence of a co-integration equation will suffice to conclude that the variables had a long run relationship.

Finding

Stationarity results

Table 1 shows stationarity results. The Exchange rate (LEXR) was stationary at 1st level but not at 1st differences as shown by the ADF and PP test and was thus had an order of integration of zero i.e $I(0)$. On the other hand, all the variables were stationary after the 1st differences and were thus integrated of order one i.e $I(1)$. Due to the different orders of integration, the appropriate model was the ARDL model.

Table 1: Unit root test

Variable	ADF		PP		Order of Integration
	At level	1 st Difference	At level	1 st difference	
LEXR	-0.0049***	0.3910	0.0003***	0.6315	I(0)
LEE	0.5349	0.0011***	0.5576	0.0000***	I(1)
LG	0.5737	0.0001***	0.3754	0.0000***	I(1)
LL	0.8976	0.0002***	0.8953	0.0002***	I(1)

LC	0.1342	0.0622*	0.4216	0.0833*	I(1)
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(*),(**) & (***) imply significance at 10%, 5% and 1% respectively

Optimal Lag selection

Optimal lag section was determined by running an unrestricted Vector Autoregressive (VAR) model. Table 2 shows LR and SC criterion gave the optimal lag of 1 while the FPE, AIC and the HQ have an optimal lag of 2. The study opted for lag 2 based on the AIC criterion the rationale being that AIC criterion performs better in small sample sizes.

Table 2: Optimal Lag selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	17.22185	NA	2.59e-07	-0.977748	-0.733973	-0.910135
1	157.3728	213.0295*	2.71e-11	-10.18983	-8.72717*	-9.78414
2	189.2689	35.72365	2.05e-11*	-10.7415*	-8.0599	-9.9977*

*imply optimal lag

Bounds Cointegration Test

Table 3 shows results of the bounds cointegration test. The bounds F-statistic was 6.759397 which was greater than the upper bounds of 10%, 5%, 2.5% and 1%. Therefore, there appears to be a long run (cointegration) relationship between the variables.

Table 3: Cointegration Test

F-statistic	10%		5%		2.5%		1%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
6.759397	3.03	4.06	3.47	4.57	3.89	5.07	4.4	5.72

Short run results

Table 4 shows short run results. In the short-term dynamics of Zambia's electricity exportation, the coefficients provide valuable insights into the impact of various factors. Lagged values of electricity export (LEE) indicate a mixed effect, with LEE(-2) showing a statistically significant negative influence, suggesting that a decrease in electricity export two periods ago is associated with a reduction in current export levels. Conversely, the exchange rate (LEXR) exhibits a complex relationship, with LEXR(-2) displaying a significant positive effect, implying that a one percent increase in the exchange rate two periods ago corresponds to a 1.43 percent increase in export levels presently. However, LEXR and LEXR(-1) are not statistically significant, indicating a lack of immediate impact of the exchange rate on electricity export. Notably, the log of electricity generated (LG) and the log of installed electricity capacity (LL) demonstrate consistently positive impacts on exportation, with all lagged values of LG and LL contributing significantly to current export levels. Specifically, a 1% increase in electricity generated leads to a 7.27%, 6.8% and 6.02% increase in electricity exports in the current, first and second periods respectively. However, other variables such as electricity consumption per capita (LNEC) do not display statistically significant effects on short-term electricity export dynamics.

The coefficient for the error correction term at lag 1 (ECT(-1)) was -1.836009 and was highly statistically significant. This coefficient suggests that in the short run, if there is a deviation from the long-run equilibrium in electricity exportation, approximately 183.6009% of that deviation will be corrected within one period. In other words, the adjustment towards the long-run equilibrium occurs at a speed of around 183.6009 percent per year. A negative coefficient for the error correction term indicates that deviations from the long-run equilibrium are corrected over time. The significance of the error correction term suggests that there is a mechanism in place that adjusts the short-term dynamics of electricity exportation to ensure that it aligns with the long-term equilibrium relationship determined by the other variables in the model. Therefore, this coefficient indicates the presence of a stable long-term relationship between the variables in the model and

the existence of a mechanism that corrects any short-term deviations from this equilibrium. These findings underscore the critical role of electricity generation and installed capacity in driving short-term fluctuations in Zambia's electricity export market, highlighting potential areas for policy intervention and infrastructure development.

Table 4: Short run results

Variable	Coefficient	Std. Error	t-statistic	p-value
LEE(-1)	-0.35865	0.265144	-1.35264	0.2092
LEE(-2)	-0.47736*	0.2139	-2.23172	0.0525
LEXR	0.777886	0.763279	1.019138	0.3347
LEXR(-1)	-0.8414	0.845033	-0.9957	0.3454
LEXR(-2)	1.426624**	0.593907	2.402101	0.0398
LG	7.276161**	2.511791	2.896802	0.0177
LG(-1)	6.820521**	3.007169	2.268087	0.0495
LG(-2)	6.028886*	2.697131	2.235296	0.0522
LL	13.45579***	3.419084	3.935496	0.0034
LL(-1)	1.559533	5.031708	0.309941	0.7637
LL(-2)	-5.83976	4.335543	-1.34695	0.2109
LNEC	-1.62114	2.681543	-0.60456	0.5604
LNEC(-1)	-5.68865	3.924449	-1.44954	0.1811
LNEC(-2)	-5.40078	4.22271	-1.27898	0.2329
C	-157.553***	29.0996	-5.41425	0.0004
@TREND	-1.00174***	0.186842	-5.3614	0.0005
ECT(-1)	-1.836009***	0.262776	-6.986978	0.0001
R-squared	0.899554	Mean dependent var	-0.03251	
Ad. R-squared	0.814561	S.D. dependent var	0.566217	
S.E. of regression	0.243828	Akaike info criterion	0.321365	
Sum squared resid	0.772876	Schwarz criterion	0.906425	
Log likelihood	7.982938	Hannan-Quinn criter.	0.483636	
F-statistic	10.5839	Durbin-Watson stat	2.232949	
Prob(F-statistic)	0.000088***			

(*),(**) & (***) imply significance at 10%, 5% and 1% respectively

Long run results

These long-run findings shed light on the enduring relationships among various factors influencing Zambia's electricity exportation: Firstly, the exchange rate (LEXR) emerges as a significant determinant, with a coefficient of 0.74243, statistically significant at the 1% level. This suggests that over the long term, a one percent increase in the exchange rate corresponds to a 0.74% increase in electricity exportation. This positive coefficient implies that a depreciation of the domestic currency relative to foreign currencies may stimulate electricity exportation, underlining the impact of currency fluctuations on export dynamics. Secondly, electricity generated (LG) exhibits a robust long-term relationship with electricity exportation, evidenced by its coefficient of 10.96158, statistically significant at the 1% level. This implies that a 1% increase in electricity generation leads to a substantial 10.96% increase in electricity exportation. Such a finding underscores the pivotal role of electricity generation capacity in driving exportation over extended periods, emphasizing the importance of investing in and maintaining sufficient generation capacity to support export activities. Thirdly, installed electricity capacity (LL) also demonstrates a significant association with electricity exportation, with a coefficient of 4.99756, statistically significant at the 5% level. This suggests that a 1%

increase in installed capacity results in a 4.99% percent increase in electricity exportation in the long run. It underscores the necessity of adequate infrastructure and capacity to facilitate electricity exports consistently, highlighting the importance of sustained investment in infrastructure development. Lastly, electricity consumption per capita (LNEC) emerges as a notable factor influencing electricity exportation, indicated by its coefficient of -6.92294, statistically significant at the 1% level. This implies that a 1% increase in electricity consumption per capita corresponds to a substantial 6.92% percent decrease in electricity exportation over the long term. The negative coefficient suggests that higher domestic electricity consumption per capita may divert electricity away from export markets, potentially due to increased domestic demand.

These long-run findings underscore the multifaceted nature of Zambia's electricity export dynamics, highlighting the interplay between exchange rates, electricity generation capacity, installed infrastructure, and domestic consumption patterns in shaping export outcomes over extended periods. Such insights are crucial for policymakers and stakeholders in formulating strategies to optimize electricity exportation and ensure the resilience and sustainability of Zambia's electricity sector.

Table 5: Long run results

Variable	Coefficient	Std. Error	t-statistic	p-value
LEXR	0.74243***	0.212519	3.49348	0.0068
LG	10.96158***	2.630107	4.167733	0.0024
LL	4.99756**	1.732952	2.883843	0.0181
LNEC	-6.92294***	1.039664	-6.65882	0.0001

(*), (**) & (***) imply significance at 10%, 5% & 1* respectively

Normality test

The error terms were normally distributed based on the Jargue-bera statistic of 1.482014 which had an associated p-value of 0.476634.

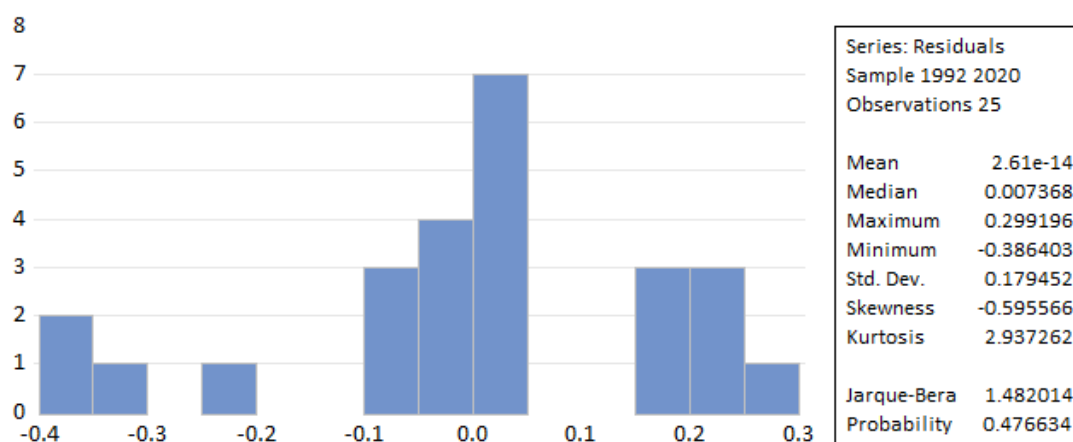


Figure 1: Normality test

Heteroscedasticity test

The Breusch-Pagan-Godfrey Heteroscedasticity test showed that the error terms were normally distributed i.e. they are homoscedastic

Table 6: Heteroscedasticity test

F-statistic	0.764664	Prob. F(15,9)	0.6897
Obs*R-squared	14.00828	Prob. Chi-Square(15)	0.5249
Scaled explained SS	1.758524	Prob. Chi-Square(15)	1

Autocorrelation Test

The Breusch-Godfrey serial correlation LM Test showed that the serial correlation was not a problem in the model.

Table 7: Autocorrelation test

F-statistic	0.192237	Prob. F(2,7)	0.8293
Obs*R-squared	1.301629	Prob. Chi-Square(2)	0.5216

Stability test

The CUSUM of squares showed stability of the model.

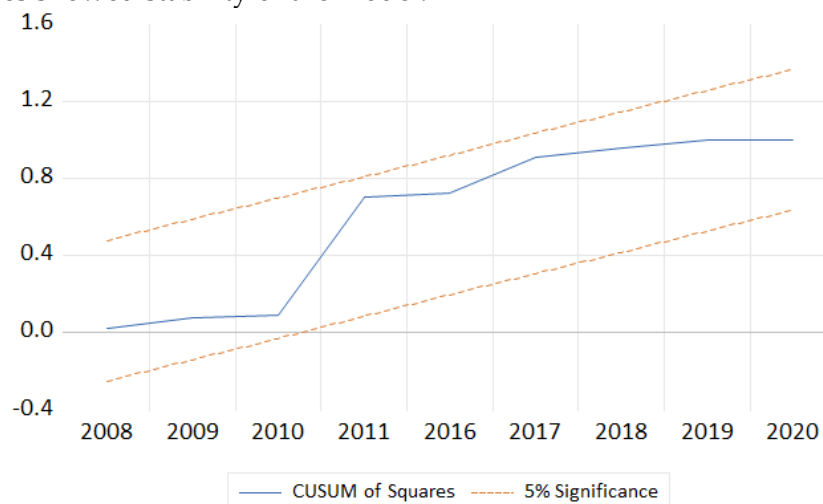


Figure 2: Stability test

Conclusion

In conclusion, the findings of this study underscore the multifaceted nature of Zambia's electricity export dynamics, revealing significant long- and short-term relationships among various economic drivers. The results highlight the pivotal role of electricity generation capacity, installed infrastructure, and exchange rate fluctuations in shaping export outcomes. Specifically, the positive impact of electricity generation capacity and installed infrastructure underscores the importance of sustained investment in infrastructure development to support and enhance electricity exportation over the long term. However, challenges such as the potential diversion of electricity due to increased domestic consumption underscore the need for careful management of domestic energy demand to ensure the availability of surplus electricity for export markets. Furthermore, the study underscores the importance of considering both short- and long-term dynamics in formulating policies and strategies aimed at unlocking Zambia's power potential and maximizing electricity exportation. Policymakers must address factors influencing exchange rates, invest in enhancing electricity generation capacity, and ensure efficient utilization of existing infrastructure to capitalize on export opportunities. Moreover, efforts to promote energy efficiency and diversify energy sources may help mitigate risks associated with increased domestic consumption. Overall, by leveraging its strengths and addressing key challenges, Zambia can position itself as a significant player in the regional electricity market, driving economic growth and enhancing energy security for the nation and its neighbours.

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