Journal of Economics and Behavioral Studies (ISSN: 2220-6140)
Vol. 17, No. 1, pp. 96-107, March 2025

Macro-Financial Determinants of Electricity Power Loss in Uganda

Alex Twinomuhwezi, *Benjamin Musiita, Frederick Nsambu Kijjambu
Faculty of Business and Management Sciences, Mbarara University of Science and Technology, Uganda
muhwezi@must.ac.ug, *bmusiita@must.ac.ug, nsambu.kijjambu@must.ac.ug
Corresponding Author: Dr Benjamin Musiita

Abstract: This study examined the macro-financial determinants of electricity power loss in Uganda, with objectives that looked at GDP per capita, inflation, lending rates, the real effective exchange rate, and energy investment in electricity power loss. This study adopted a time series quantitative methodology. The secondary data was collected from reliable sources such as the World Bank, the Bank of Uganda, and the Electricity Regulatory Authority, spanning 20 years. The research applied a VAR model to analyze the short-run dynamics of the variables under consideration. The data were first cleaned to handle heteroscedasticity issues and missing values. The study found some of Uganda's most significant determinants of electricity losses to be macro-financial factors such as inflation, GDP per capita differences, and energy investment. Inflation volatility increased power losses, as did differences in GDP per capita, while low investment in energy translated to inefficiency within the electricity sector. Lending rates inhibited the infrastructural development of energy and, hence, power distribution and transmission efficiency. Therefore, the study concludes that addressing these macro-financial factors- inflation control, efficient energy investment, and economic policies- minimizes losses of electricity power in Uganda. This study suggests focusing on inflation stabilization, attracting investment in the energy sector, controlling the lending rate, and upgrading energy infrastructure management for better efficiency in the overall Ugandan electricity system. In addition, addressing issues of exchange rates and modern energy distribution technologies is central to minimizing losses and promoting an efficient energy sector.

Keywords: *Electricity power loss, GDP per capita, inflation, lending rates, real effective exchange rate, energy investment*.

1. Background to the Study

Effective electricity power loss management creates economic stability and growth in a nation. As noted by the International Energy Agency (2024), an efficient and continuous electricity supply has been linked with economic growth, whereby, on an increased scale, industry, agriculture, and services have ensured higher productivity. According to the World Bank (2020), reliable electricity is essential to boost productivity and jobs and increase living standards. A stable power supply facilitates the operation of industries and innovations, facilitating economic growth. World Bank 2020. On the other hand, electricity power loss is considered a significant challenge in attaining a reliable power system; this refers to the difference between the amount of electricity produced and that delivered to the consumer. Sadovskaia et al. 2019. The International Energy Agency (2023) explains that globally, the power loss rate ranges from 8% to 15%, while in developing countries, it is higher because of poor infrastructure and inefficiencies in the electricity grid. International Energy Agency, 2023.

The situation is even more dire in Africa, with some regions reporting power losses exceeding 20% due to outdated transmission lines, high rates of non-technical losses like theft, and other technical inefficiencies (African Climate Foundation, 2022). Power losses have been a longstanding issue in Uganda, ranging from 15% to 25% in recent years (Wabukala et al., 2022). These losses are attributed to a combination of technical inefficiencies in transmission and distribution networks and non-technical factors such as power theft and poor management of the electricity grid (Wabukala et al., 2022). From 2020 to 2024, global electricity production has shown a steady increase. According to the International Energy Agency (2023), 2020 global electricity production was about 25,000 terawatt-hours (TWh), increasing to about 26,000 TWh in 2021 and 27,000 TWh in 2022. In 2023, it indicated a 2.6% growth, aligning with historical trends; similar growth was evident in 2024 (Memarzadeh et al., 2025). In Africa, electricity production has grown similarly, increasing from 1,200 TWh in 2020 to about 1,250 TWh in 2021 and 1,300 TWh in 2022. The African Climate Foundation (2022) postulates that the regional electricity demand will continue to grow at an annual growth rate of 4%, with renewable energy meeting about two-thirds of this demand. In the same trend, the electricity generation in Uganda increased from 5,000 GWh in 2020 to an estimated 6,000 GWh in 2022, according to Iddi et al. (2024), according

to the Uganda Electricity Regulatory Authority. (2024), the installed capacity for Uganda stood at over 2,000 MW as of 2024 and is anticipated to increase even more in the coming years. However, this recent progress has been overshadowed by the challenge of power loss, which is considered a detraction from the potential benefit of improved generation. The causes of these losses include outdated infrastructure, high illegal connection rates, and inefficiencies in transmission and distribution systems that cause power losses and make the delivery of electricity to consumers inefficient (Wabukala et al., 2022).

GDP per capita, inflation, lending rates, the real effective exchange rate, and energy investment are some of the key macro-financial determinants of electricity power loss. According to the International Energy Agency (2024), GDP per capita is a critical factor in shaping the trend of energy consumption. With increased income levels, the demand for energy goes up, although whether this demand can be satisfied is determined by the efficiency of the energy sector in a country. In Uganda, one of the significant factors that has limited the development of the energy infrastructure to minimize power losses is low GDP per capita. The restricted economic capacity lowers the ability of the country to invest in renovating transmission and distribution networks, leading to higher technical losses (Simionescu et al., 2019). Inflation is also important in the electricity sector, as increases may translate to an increase in tariffs, reducing affordability and dissuading consumers from paying for energy use. According to Bednář et al. (2022), in the case of an inflationary spiral, the cost of electricity reduces consumers' ability to access reasonably affordable power and, even more importantly, increases power theft and non-payment issues. The following important macro-financial determinant for energy investment is the rate of lending. According to Dokas et al. (2022), high lending rates deter domestic and foreign investments in energy infrastructure, which is crucial for reducing technical losses and enhancing power delivery efficiency.

Furthermore, volatility in the real effective exchange rate can raise the price of imported energy infrastructure, such as transformers and other necessary equipment. This to Stern et al. (2019, this can increase the cost of upgrading obsolete power systems. Therefore, the ultimate goal of minimizing power losses in developing countries such as Uganda is retarded. Finally, energy investment is an important determinant indicating the electricity supply's efficiency. As noted by Wabukala et al. (2022), inadequate investment in Uganda's energy sector has contributed to the persistence of inefficiencies in the grid, hence continuing to cause power losses. According to the exogenous growth model, these factors constitute the overall performance of Uganda's electricity sector. Given this context, integrated policy intervention at both the financial and infrastructural levels is pertinent in reducing power loss and making the sector sustainable.

2. Literature Review

Theoretical Literature

Exogenous growth model

The theoretical underpinning for this study emanates from the exogenous growth model, first postulated by Robert Solow in 1956. This model postulates that long-run economic growth depends on exogenous variables such as technological progress, capital accumulation, and labor growth (Pérez & Ortega, 2021). According to the Exogenous Growth Model, these external variables, especially technological changes, are the major causes of economic growth as they enhance productivity and output. Atangana & Goufo, 2022. In this context, the Exogenous Growth Model has been used in this study to establish how the macro-financial factors of GDP per capita, inflation, real effective exchange rate, lending rate, and energy investment affect electricity power loss in Uganda. For example, GDP per capita, which reflects a country's standard of living, can influence energy demand and, consequently, the efficiency of electricity transmission and distribution (Islam & Islam, 2021).

Inflation affects the cost of energy production, which can lead to inefficiencies and power losses if not properly managed (Olivares et al., 2023). The real effective exchange rate impacts the cost of imported technologies and infrastructure, significantly improving the electricity grid's reliability and reducing power losses (Hassan et al., 2021). Lending rates also influence investments in the energy sector, as high lending rates can deter energy infrastructure development, leading to more frequent power losses (Islam & Islam, 2021). As a key driver of infrastructure development, energy investment is directly linked to reducing technical and non-technical losses in the power sector (Wabukala et al., 2022). While the Exogenous Growth Model focuses on the role of external factors in economic growth, a limitation is its assumption that external factors drive technological

advancements without considering the impact of domestic policies (Hassan et al., 2021). This study mitigates this limitation by incorporating factors such as government policies, energy investments, and domestic efforts to improve electricity infrastructure; hence, analyzing the loss of electricity power in Uganda becomes more comprehensive (Wabukala et al., 2022).

Empirical literature review

The relationship between GDP per capita and electricity power loss

The relationship between GDP per capita and electricity power loss is complex, involving economic growth, energy consumption, and infrastructure development. With countries experiencing an increase in GDP per capita, electricity demand usually rises to reflect a more improved standard of living, higher rates of industrialization, and an increased population relying on energy services (Kabeyi & Olanrewaju, 2021). However, this increase in electricity demand often exposes weaknesses in the electricity grid, potentially leading to higher power losses, especially in developing countries with outdated infrastructure (Wabukala et al., 2023). Therefore, increasing per capita GDP would nullify any economic benefits within a country since the inefficiency of the electric sector would augment the losses experienced through poor management, inadequate technology, and even the lack of investment in electricity infrastructure (Abbasi et al., 2021). According to Tudor and Sova (2021), economic growth might have driven the rise in energy consumption. However, reductions in electricity power loss for a country depend mainly on the efficiency of its energy infrastructure, which usually falls behind the high economic growth rates. Sometimes, greater GDP per capita corresponds with an expansion in the industrial sectors that are highly energy-intensive, further putting stress on existing energy systems (Szustak et al., 2021). This strain often leads to technical losses due to inefficient transmission and distribution networks.

In contrast, non-technical losses, such as theft, can be very high and elevate the overall power loss figures (Wabukala et al., 2023). Moreover, Chen et al. (2023) reveal that countries with high GDP per capita are more likely to face power outages, as conventional energy systems cannot cope with the rapidly growing demand for energy and cause disruptions potentially harmful to national economic growth. However, when GDP per capita increases, governments can make more substantial investments in energy infrastructure to reduce these losses and provide better grid stability, as discussed by Das & McFarlane (2022). With a solid energy sector, reliable electricity would further allow continuous economic growth through further enhancement in GDP per capita, forming a self-reinforcing cycle (Wang et al., 2022). Failure in electricity power loss may cause inefficiencies in hindering economic growth; thus, proper alignment of energy policy to objectives set for economic development should be addressed to not waste energy in producing inefficiency instead of driving forward the economic front (Abbasi et al., 2021). This thus portrays an almost intricately related condition between GDP per capita and electricity power loss, where focused investments and reforms must complement adequate energy infrastructure to avoid undermining economic growth benefits (Szustak et al., 2021).

The relationship between Inflation and electricity power loss

The relationship between inflation and loss of electricity power is complex because inflation may affect electricity consumption, energy prices, or the efficiency of the energy systems. Inflation is usually sustained by an increase in the general price level of goods and services that often increases the prices of electricity, thus affecting its demand and the way supply is managed (Bednář et al., 2022). With increased inflation, the price of electricity also tends to increase, creating economic burdens for consumers and industries, especially in developing countries, as stated by Adi et al. (2022). This increased energy cost may lead to lower energy consumption and hence impact the overall electricity demand and utilities' capacity to manage power loss effectively, according to Steinberg et al. (2023). Higher electricity prices, driven by inflation, may also cause consumers to adopt energy-saving behaviors, which can inadvertently reduce utility revenue, limiting their ability to invest in infrastructure and maintenance, thus exacerbating power losses (Roeger & Welfens, 2022).

Additionally, inflation can impact the ability of governments and energy providers to fund necessary upgrades to energy infrastructure, as rising costs often constrain public spending (Abdallah & Kpodar, 2023). The relationship between inflation and power loss is also influenced by the macroeconomic environment, where inflationary pressures can reduce the purchasing power of both consumers and energy companies, preventing the replacement of outdated transmission and distribution infrastructure that contributes to power loss (Magweva & Sibanda, 2020). Inflation can sometimes worsen technical inefficiencies in the electricity sector, as

companies may delay investments in modernizing grid systems due to the high costs associated with inflationary pressures (Razavi & Fleury, 2019). Furthermore, inflation might raise the operating costs of an energy company to the point of forcing it to increase prices further or reduce the quality of the service. It may lead to frequent power outages and higher technical losses (Shapiro, 2022). Therefore, uncontrolled or high inflation could bring about a snowballing effect whereby the increased cost of electricity leads to less investment in energy infrastructure and, eventually, to increased power loss due to Gutium (2019. This issue is particularly evident in developing countries, where inflationary spirals can severely affect the quality of electricity supply, as seen in countries with high energy inefficiencies (Razavi & Fleury, 2019).

Additionally, inflation affects the fuel cost used in electricity generation, influencing the overall cost of electricity production and delivery (Eickmeier & Hofmann, 2022). As fuel prices increase, energy providers may pass on the cost to consumers, exacerbating inflation further and creating a situation where the economic burden of higher electricity prices makes it more difficult for consumers to pay their bills, leading to increased instances of non-technical losses such as theft or illegal connections (Abdallah & Kpodar, 2023). It becomes a vicious circle because inflation and loss of power feed into each other, especially in developing countries where infrastructure is largely old and inadequate to handle increased demand and higher costs (Magweva & Sibanda, 2020). Overall, inflation plays a crucial role in shaping the dynamics of electricity power loss, as it impacts not only consumers' economic conditions but also energy providers' capacity to maintain and upgrade their systems to reduce inefficiencies and losses (Ridzuan et al., 2020).

The relationship between the Lending rate and electricity power loss

The relationship between lending rates and electricity power loss is complex and influenced by various macroeconomic and sectoral dynamics. Lending rate, being the cost of borrowing both for businesses and individuals, may significantly affect the electricity providers' capacity to invest in infrastructure, thus reducing power losses. When lending rates are high, energy companies face increased financing costs for infrastructure projects, which can delay or limit investments in modernizing grid systems and reducing technical losses (Si et al., 2021). This can also exacerbate inefficiencies in electricity transmission and distribution, as outdated infrastructure is more prone to power loss, leading to higher operational costs (Ridzuan et al., 2020). Similarly, high lending rates can discourage private investment in the energy sector, particularly in developing countries, where capital for electricity grid upgrades is already limited (Obafemi, 2021). The higher cost of borrowing can further restrict the ability of energy firms to implement technologies that could improve the efficiency of electricity delivery and reduce losses (Grant et al., 2023). In this respect, increased interest rates could result in higher electricity prices because utility firms pass on the increase in their borrowing costs to the people; thus, electricity consumption is reduced, or non-technical losses like theft may increase (Abu-Rayash & Dincer, 2020). This is especially the case in terms of deregulation, where liberalization of lending rates may lead to financial instability within energy firms, making it more difficult for them to maintain and upgrade essential infrastructure (Si et al., 2021). The high lending rates further contribute to a tight credit environment that may prohibit consumers from financing energy-efficient appliances or renewable energy solutions, adding to electricity power losses (Coskun & Korn, 2021).

Furthermore, the broader economic environment plays a critical role, as high lending rates can suppress overall economic growth, leading to lower electricity consumption and further exacerbating the inefficiency of energy distribution networks (Deryugina et al., 2020). As energy providers face more financial constraints, they may focus on short-term survival rather than long-term improvements, thus increasing the likelihood of technical and non-technical electricity losses (Sam, McNown, & Goh, 2019). Thus, lending rates indirectly affect electricity power loss by influencing the financial viability of energy companies and consumer behavior, with high rates contributing to increased power inefficiencies across the sector (Ridzuan et al., 2020).

The relationship between the real effective exchange rate (REER) and electricity power loss

The REER and electricity power loss are related in their macroeconomic and sectoral determinants, which interact in shaping the efficiency of energy markets. The REER plays a crucial role in determining the competitiveness of a country's energy sector, as fluctuations in exchange rates can directly impact the cost of importing energy, energy technologies, and raw materials necessary for power generation (Patel et al., 2019). A real exchange rate depreciation is usually associated with increased costs of imported energy resources, higher overall costs of generating and transmitting electricity, and, thus, the price of electricity to consumers

(Edwards, 2019). This, in turn, may lead to higher energy consumption costs and the potential for inefficiencies in electricity distribution, especially if energy companies cannot absorb the rising costs (Paudel et al., 2020). Moreover, a weaker exchange rate may prompt governments to raise electricity tariffs to cover higher import costs, exacerbating electricity theft and non-payment of electricity bills, ultimately increasing power loss (Saqib et al., 2021).

On the other hand, appreciation of the exchange rate might decrease the price of energy importation; hence, companies have a better financial record, enabling them to reinvest in modernizing infrastructure to reduce technical losses. According to Dornbusch (2019), the relationship between REER and electricity power loss becomes more complex because of the interlinkages of the exchange rate and the world energy market, remarkably, the oil price. Fluctuations in oil prices, often tied to exchange rate movements, can significantly impact the cost of electricity generation, especially in oil-dependent economies, which may increase electricity losses (Beckmann et al., 2020). Moreover, foreign exchange regimes also influence the impact of the REER on the energy sector, as more volatile exchange rates often lead to more significant uncertainty in energy markets and can deter long-term investment in energy infrastructure (Saqib et al., 2021). A stable REER, in contrast, can encourage investment in energy efficiency improvements and infrastructure upgrades that can reduce the loss of power.

Furthermore, the REER may affect even the availability of financing for energy projects, whereby countries with favorable exchange rates find it easier to attract foreign capital to improve energy infrastructure, hence reducing power loss (Kumar, 2019). However, a strong REER can minimize the cost of energy in emerging economies, further aiding access to improved energy security by reducing theft cases and overall power losses within the networks (Abdin & Mérida, 2019). In sum, REER can impact power losses in electricity supply due to three pathways of effects: imported energy price channels, invested capital and infrastructural spending channels, and the overall general state of the economy.

The relationship between Energy investment and electricity power loss

The relationship between energy investment and electricity power loss is important in knowing the efficiency level of energy systems and their resultant capacity to reduce losses. Energy investment improves energy infrastructure by enhancing grid reliability and capacity, directly reducing electricity power losses (Özdemir et al., 2020). These have been identified to contribute towards a resilient and diversified energy supply, which can help decrease power outages and transmission losses (Lehtola & Zahedi, 2019). Further, targeted investment in energy storage technologies, which would further the intermittent renewable sources, can reduce losses associated with fluctuations in supply by offering stabilizing influences on grid performance (Bigerna et al., 2019). In emerging economies such as Uganda, investments in renewable energy and power sector reforms have enhanced electricity generation capacity, reducing the strain on the grid and mitigating power losses (Probst et al., 2021).

Energy investment also encourages the modernization of transmission and distribution infrastructure, which is crucial for minimizing technical losses, especially in developing regions where the grid is often outdated and inefficient (Godinho & Eberhard, 2019). Moreover, the implementation of advanced technologies such as smart grids, which are supported by energy investments, helps to monitor and control power flows, identify loss points, and optimize energy distribution (Sridharan et al., 2020). Investment in energy efficiency measures, alongside renewable energy deployment, not only improves the sustainability of power systems but also reduces the operational costs that contribute to excessive energy losses (Maulidia et al., 2019). The impact of energy investments on reducing power losses is further amplified by the commitment to long-term energy planning and policy reforms, which ensure that investments are directed towards sustainable and efficient energy systems (Trotter et al., 2019). However, against all the positive impacts of energy investment, inhibitors to electricity security include inadequacies within the regulatory frameworks and financial constraints, which restrict or affect investment efforts in minimizing power losses: Wabukala et al., 2022. As seen in Uganda, for instance, overcoming these barriers requires coordinated efforts from both the public and private sectors to maximize the benefits of energy investments in enhancing grid reliability and reducing power losses (Migisha et al., 2024).

3. Methodology

The methodology of this study was designed to comprehensively examine the macro-financial determinants of electricity power losses in Uganda using a quantitative approach. A time series analysis framework was employed, which allowed for exploring trends and relationships between macro-financial variables and electricity power losses over 20 years (Dokas et al., 2022). Secondary data were collected from reliable sources, including the World Bank, the Bank of Uganda, the Electricity Regulatory Authority, and national statistics (World Bank, 2024). The dependent variable, electricity power losses, was measured as a percentage of total power generated (Murshed and Ozturk, 2023). In contrast, the independent variables included the GDP growth rate, inflation rate, exchange rate fluctuations, public and private energy investments, electricity tariffs, and energy subsidies (Durani et al., 2024). To ensure the stationarity of the time series data, the study conducted Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, as non-stationary data could have led to unreliable results (Musbah, Aly, and Little, 2023). Johansen's cointegration test was used to identify long-term relationships between the variables, while the Error Correction Model (ECM) captured short-term dynamics in alignment with long-term equilibrium (Laksono, 2024). Granger Causality tests assessed the directional causality between the macro-financial variables and electricity power losses (Dokas et al., 2022). To ensure the robustness of the results, the study performed tests for autocorrelation (Durbin-Watson test), heteroscedasticity (Breusch-Pagan test), and multicollinearity (Variance Inflation Factor) (Ohaegbulem and Iheaka, 2024). Descriptive statistics, such as mean, standard deviation, and range, summarized the dataset, while trend analysis and multiple regression models estimated the relationships between the variables. The model fit was evaluated using R-squared, adjusted R-squared, and F-statistics. The data analysis was conducted using econometric software, specifically STATA, and proper attribution of data sources was maintained to adhere to ethical standards.

Table 1: Data characteristics and data management

Variables	Obs	Mean	Std. Dev.	Min	Max
eloss	33	28.38485	7.967713	16.4	39
gdppercapita	33	1395595	1200120	100793.6	3761142
inflationg	33	10.17962	16.43445	-3.16956	85.35327
lending_rate	33	21.85455	4.301169	18.2	39.1
realeffec	33	113.4229	20.52619	92.12739	179.9531
investment	13	1.22E+08	2.29E+08	18100000	8.72E+08

The summary statistics highlight significant variability across key macro-financial factors in Uganda. *Electricity loss, measured as a percentage difference between the amount of electricity bought and sold,* demonstrates moderate variation with a mean of 28.38 (SD = 7.97), while *GDP per capita* reveals substantial inequality, ranging from UGX 100,793.6 to UGX 3,761,142 (mean = UGX 1,395,595, SD = UGX 1,200,120). *Inflation* shows marked volatility (mean = 10.18, SD = 16.43), with values ranging from deflationary levels (-3.17) to 85.35, reflecting macroeconomic instability. Relatively stable measures include the *lending rate* (mean = 21.85, SD = 4.30) and the *real effective exchange rate* (mean = 113.42, SD = 20.53). However, *investment* data (mean = UGX 122 million, SD = UGX 229 million) shows extreme disparities, with a range from UGX 18.1 million to UGX 872 million.

These variations underscore the need for this study to better understand the relationships among these variables and their implications for electricity efficiency in Uganda. The substantial heteroscedasticity observed, particularly in variables like *GDP per capita*, *inflation*, and *investment*, necessitated the application of log transformations to normalize distributions and reduce skewness, enabling more robust statistical analysis and interpretation. Similarly, the variable energy investment, which had many missing observations, was linearly interpolated to fill in the missing observations. This allowed analysis to proceed.

Table 2: Collinearity Diagnostics

Variables	VIF	SQRT VIF	Tolerance	R-Squared
GDPPC	3.57	1.89	0.2805	0.7195
INFL	1.33	1.15	0.7498	0.2502
LR	1.55	1.24	0.6457	0.3543
REER	3.38	1.84	0.2961	0.7039
ENERGY_INV	4.21	2.05	0.2376	0.7624
Mean VIF	2.81			

The collinearity diagnostics reveal that all variables have a Variance Inflation Factor (VIF) below the commonly accepted threshold of 10, indicating no severe multicollinearity issues in the dataset. ENERGY_INV exhibits the highest VIF (4.21), suggesting moderate collinearity, while INFL has the lowest VIF (1.33), indicating minimal multicollinearity. The mean VIF is 2.81, further supporting the absence of problematic multicollinearity. Overall, the results suggest that the study variables can be included together in the same model with no immediate need for corrective measures regarding collinearity.

Variable Stationarity and Cointegration

Variables were found to exhibit mixed orders of integration. A cointegration test was carried out among the non-stationary series and no cointegration was found using the Johansen cointegration test.

Model Estimation

The study proceeded to estimate a VAR model with differenced variables, based on the following justifications. Although variables exhibited mixed orders of integration, there was no evidence of cointegration among the non-stationary series. A VAR model with differenced variables is efficient in that it allows interpretation of the short-run dynamics of such variables.

4. Results

Table 3: VAR Model

D_ELOSS						
ELOSS						
LD.	.7611035	.0977812	7.78	0.000	.5694559	.9527511
L2D.	.5739792	.1178662	4.87	0.000	.3429657	.8049926
L3D.	-.4332212	.1463151	-2.96	0.003	-.7199934	-.1464489
L4D.	.523297	.0665513	7.86	0.000	.3928588	.6537351
GDPPC						
LD.	-.2648018	.1059047	-2.50	0.012	-.4723712	-.0572325
L2D.	.9340965	.138901	6.72	0.000	.6618555	1.206338
L3D.	.1999771	.0824711	2.42	0.015	.0383366	.3616176
L4D.	.2199378	.1128796	1.95	0.051	-.0013021	.4411777
INFL						
L1.	.0745311	.0166324	4.48	0.000	.0419321	.1071301
L2.	-.1282401	.0224702	-5.71	0.000	-.1722809	-.0841992
L3.	-.0255869	.0081997	-3.12	0.002	-.0416581	-.0095157
L4.	-.0093454	.0124621	-0.75	0.453	-.0337707	.0150799
LR						
L1.	-1.129187	.1637375	-6.90	0.000	-1.450107	-.8082673
L2.	1.882869	.2360365	7.98	0.000	1.420246	2.345492
L3.	-.5170106	.1594004	-3.24	0.001	-.8294297	-.2045915
L4.	.6542883	.0743839	8.80	0.000	.5084986	.8000779
REER						
LD.	.569573	.1857928	3.07	0.002	.2054258	.9337202
L2D.	-.908702	.1541798	-5.89	0.000	-1.210889	-.6065152
L3D.	.3649806	.1354452	2.69	0.007	.0995129	.6304483
L4D.	.0515963	.1299939	0.40	0.691	-.203187	.3063797

Discussion

The results of this study provided significant information about the macro-financial determinants of electricity power loss in Uganda, concerning the relationship between GDP per capita, inflation, lending rate, REER, and energy investment. These results bring about an understanding of the complex dynamics that affect electricity efficiency in the country and are fairly consistent with prior studies in different contexts.

Electricity Loss and Macroeconomic Indicators

The analysis showed that Uganda's average value of electricity loss stood at a moderate value of 28.38% with a significant variation = 7.97. This moderate variation means that while the loss of electricity is a significant issue, it does not occur uniformly across the country. Previous studies, such as that of Adams et al. (2020), identified similar patterns in South Africa, where electricity transmission and distribution losses were influenced by economic growth. The authors attributed such high levels of electricity loss to infrastructural inefficiencies and the general state of the economy. Our findings support this hypothesis, as Uganda's electricity distribution may be exacerbated by general macroeconomic instability and energy infrastructure inefficiencies..

GDP per Capita and Electricity Power Loss

The study found that GDP per capita in Uganda exhibited substantial inequality, with a mean of UGX 1,395,595 (SD = 1,200,120). This highlights significant economic disparities across the country. Previous studies, like those by Simionescu et al. (2019), have suggested that higher GDP per capita is generally associated with improved energy efficiency. However, the vast disparities in Uganda's GDP suggest that economic growth might not necessarily translate into reduced electricity power loss due to other systemic issues, such as inefficient infrastructure or the challenges posed by energy theft. Therefore, while economic growth plays a role, it is not the sole determinant of electricity loss.

Inflation and Electricity Power Loss

The observed inflation rate in Uganda was quite volatile, with a mean of 10.18 and a standard deviation of 16.43, depicting macroeconomic instability. This is supported by the findings of Bednář et al. (2022), who observed that in an emerging economy, inflationary tendencies are likely to translate into increased energy costs and inefficiency in electricity use. High inflation in Uganda could increase the operational cost for companies selling electricity and thus lead to an increase in power losses. Besides, inflation may discourage investors from investing in energy infrastructure, as stated by Saqib et al. (2021), where high inflationary pressures reduced investment in the energy sector, further worsening the technical efficiency of electricity distribution.

Lending Rate and Electricity Power Loss

The study also realized a relatively stable lending rate with a mean of 21.85 and a standard deviation of 4.30, which was associated with energy sector investments. High lending rates usually raise the cost of borrowing, with the effect of reducing the ability of energy companies to invest in much-needed infrastructure upgrades. This finding is in tandem with Si et al. (2021), who, while noting that high interest rates in developing countries discouraged investments in energy infrastructure, leading to operational inefficiencies and higher electricity losses, called for the need to ensure low interest rates. Therefore, Uganda's lending rate tends to limit energy investments and could worsen the situation in terms of loss of electricity.

Real Effective Exchange Rate (REER) and Electricity Power Loss

The study found that in the case of Uganda, the REER has a significant relationship with electricity power loss. The mean and SD for the REER in Uganda were 113.42 and 20.53, respectively. A high REER may indicate the appreciation of a country's currency against its trading partners, hence increasing access to imported energy technologies by reducing their cost. However, REER volatility creates uncertainty in energy prices and hence affects investment in energy infrastructure. This dynamic is further justified by the results of Beckmann et al. (2020), who noticed that the changes in the exchange rate have considerable consequences for energy pricing, which influences the cost of electricity and, thus, the efficiency of power transmission and distribution.

Energy Investment and Electricity Power Loss

Energy investment showed a very wide variation, with an average of UGX 122 million and a very high SD (SD = UGX 229 million). This huge variation in the energy investment depicts that some regions or companies might invest hugely in their energy infrastructure, while others have not put much in place. This result aligns with the

study of Probst et al. (2021), which explained that the continuous inefficiency within the power sector has been due to inadequate investment in energy infrastructure within Uganda. Inconsistencies in the investment of energy can, therefore, be directly attributed to the high level of electricity power loss observed in Uganda.

Collinearity and Statistical Considerations

The collinearity diagnostics indicated no severe multicollinearity issues in the dataset, with all Variance Inflation Factors (VIFs) being below the commonly accepted threshold of 10. This finding is consistent with the study of Ridzuan et al. (2020), who found no major multicollinearity problems in their energy consumption models in Malaysia. The absence of multicollinearity ensures that the variables can be included in the same model without the need for corrective measures, thereby supporting the robustness of the analysis.

Model Estimation and Short-Run Dynamics

As the orders of integration for the variables were mixed and no cointegration was found, the Vector Autoregressive model was estimated with the differences of the variables. This is supported by Abdallah and Kpodar (2023) through the use of VAR models that study dynamic relationships among macroeconomic variables in investigations of inflation and energy prices. The estimation of this model allowed the interpretation of the short-run dynamics, crucial to understanding how these macro-financial determinants interact in the energy sector in Uganda, given the absence of any long-run equilibrium relationships.

5. Conclusion and Recommendations

In conclusion, this study provides valuable insights into the macro-financial determinants of electricity power loss in Uganda. The high contribution from changes in GDP per capita, inflation, the lending rate, the real effective exchange rate, and energy investment to alterations in electricity power loss could be emphasized from the findings. Having established mixed integration orders, a VAR model with differenced variables was estimated to analyze the short-run dynamics. Strong results of the VIF below indicate the absence of severe multicollinearity, hence strengthening the robustness of the model. The study stresses that addressing macro-financial factors-in particular, inflation and energy investment through policies-will minimize electricity power losses, hence increasing the general efficiency in the energy sector in Uganda. These results also contribute to the knowledge on the complex interaction between economic variables and the efficiency of electricity, which might inform future strategies in reforming and investing in the energy sector.

Recommendations

Results from this study have indicated that macro-financial variables such as inflation, GDP per capita, lending rates, the real effective exchange rate, and energy investments are significant in explaining variations in the loss of electricity power in Uganda. Therefore, to address the persistent power losses, policymakers must implement strategies that stabilize inflation, encourage sustainable energy investments, and enhance economic growth. Additionally, improving the management of the energy sector, addressing exchange rate fluctuations, and fostering technological advancements in energy transmission and distribution will contribute to minimizing power losses and improving the efficiency of Uganda's electricity system.

References

Abbasi, K. R., Hussain, K., Abbas, J., Adedoyin, F. F., Shaikh, P. A., Yousaf, H., & Muhammad, F. (2021). Analyzing the role of industrial sector's electricity consumption, prices, and GDP: a modified empirical evidence from Pakistan. Aims Energy, 9(1), 29-49.

Abdallah, C., & Kpodar, K. (2023). How large and persistent is the response of inflation to changes in retail energy prices?. Journal of International Money and Finance, 132, 102806.

Abdin, Z., & Mérida, W. (2019). Hybrid energy systems for off-grid power supply and hydrogen production based on renewable energy: A techno-economic analysis. Energy Conversion and Management, 196, 1068-1079.

Abu-Rayash, A., & Dincer, I. (2020). Analysis of the electricity demand trends amidst the COVID-19 coronavirus pandemic. Energy Research & Social Science, 68, 101682.

Adams, S., Atsu, F., Klobodu, E. M., & Richmond, L. (2020). Electricity transmission, distribution losses and economic growth in South Africa. Heliyon, 6(11).

Adi, T. W., Prabowo, E., & Prasadjaningsih, O. (2022). Influence of electricity consumption of industrial and business, electricity price, inflation and interest rate on GDP and investments in Indonesia. International Journal of Energy Economics and Policy, 12(3), 331-340.

African Climate Foundation. (2022). *Energy data challenges in Africa's electricity landscape*. African Climate Foundation.

Atangana, A., & Goufo, E. F. D. (2022). Modern and generalized analysis of exogenous growth models. Chaos, Solitons & Fractals, 163, 112605.

Beckmann, J., Czudaj, R. L., & Arora, V. (2020). The relationship between oil prices and exchange rates: Revisiting theory and evidence. Energy Economics, 88, 104772.

Bednář, O., Čečrdlová, A., Kadeřábková, B., & Řežábek, P. (2022). Energy prices impact on the inflationary spiral. Energies, 15(9), 3443.

Bigerna, S., Wen, X., Hagspiel, V., & Kort, P. M. (2019). Green electricity investments: Environmental target and the optimal subsidy. European Journal of Operational Research, 279(2), 635-644.

Chen, H., Jin, L., Wang, M., Guo, L., & Wu, J. (2023). How will power outages affect the national economic growth: Evidence from 152 countries. Energy Economics, 126, 107055.

Comin, D. A., Johnson, R. C., & Jones, C. J. (2023). Supply chain constraints and inflation (No.. w31179). National Bureau of Economic Research.

Coskun, S., & Korn, R. (2021). Modeling the intraday electricity demand in Germany. Mathematical modeling, simulation and optimization for power engineering and management, 3-23.

Das, A., & McFarlane, A. (2022). Remittances, electricity consumption and electric power losses in Jamaica. Journal of Economic Studies, 49(3), 558-575.

Deryugina, T., MacKay, A., & Reif, J. (2020). The long-run dynamics of electricity demand: Evidence from municipal aggregation. American Economic Journal: Applied Economics, 12(1), 86-114.

Dokas, I., Panagiotidis, M., Papadamou, S. and Spyromitros, E., 2022. The determinants of energy and electricity consumption in developed and developing countries: International evidence. *Energies*, *15*(7), p.2558.

Dokas, I., Panagiotidis, M., Papadamou, S., & Spyromitros, E. (2022). The determinants of energy and electricity consumption in developed and developing countries: International evidence. Energies, 15(7), 2558.

Dornbusch, R. (2019). The theory of flexible exchange rate regimes and macroeconomic policy. In Flexible Exchange Rates/h (pp. 123-143). Routledge.

Durani, F., Anwar, A., Sharif, A., Hamid, A., Ali, S. and Syed, Q.R., 2024. Exploring the link between inflation, tourism, trade, foreign direct investment, and renewable energy consumption: evidence from a novel wavelet quantile correlation approach. *Clean Technologies and Environmental Policy*, pp.1-15.

Edwards, S. (2019). Real Exchange Rates in Developing Countries: Concepts and Measurement 1. In International financial markets and agricultural trade (pp. 56-108). CRC Press.

Eickmeier, S., & Hofmann, B. (2022). What drives inflation? Disentangling demand and supply factors.

Godinho, C., & Eberhard, A. A. (2019). Learning from power sector reform: The case of Uganda. World Bank Policy Research Working Paper, (8820).

Grant, L., Latchman, H., & Alli, K. (2023). Detection of electricity theft in developing countries machine learning approach. Trends in Computer Science and Information Technology, 8(2), 038-049.

Gutium, T. (2019, October). The Correlation between Energy Resources Tariffs, Inflation and Competitiveness. In 2019 International Conference on Electromechanical and Energy Systems (SIELMEN) (pp. 1-6). IEEE.

Hassan, M. A., Bailek, N., Bouchouicha, K., & Nwokolo, S. C. (2021). Ultra-short-term exogenous forecasting of photovoltaic power production using genetically optimized non-linear auto-regressive recurrent neural networks. Renewable Energy, 171, 191-209.

Iddi, E. S., Umaru, K., Eze, V. H. U., Asikuru, S., Musa, N., & Ochima, N. (2024). Voltage Optimization on Low-Voltage Distribution Transformer Zones Using Batteries in Uganda. Journal of Engineering, Technology, and Applied Science (JETAS), 6(1), 40-48.

International Energy Agency. (2022). *World electricity capacity and demand*. International Energy Agency.

International Energy Agency. (2023). *Electricity market report – January 2023*. International Energy Agency.

International Energy Agency. (2024). *Electricity 2024: Executive summary*. International Energy Agency.

Islam, M. M., & Islam, M. S. (2021). Energy consumption–economic growth nexus within the purview of exogenous and endogenous dynamics: evidence from Bangladesh. OPEC Energy Review, 45(2), 191-216.

Itskhoki, O., & Mukhin, D. (2021). Exchange rate disconnect in general equilibrium. Journal of Political Economy, 129(8), 2183-2232.

Kabeyi, M. J. B., & Olanrewaju, O. A. (2021, December). Relationship between electricity consumption and economic development. In 2021 International Conference on Electrical, Computer and Energy Technologies (ICECET) (pp. 1-8). IEEE.

Kumar, S. (2019). Asymmetric impact of oil prices on exchange rate and stock prices. The Quarterly Review of Economics and Finance, 72, 41-51.

Laksono, R., 2024. Analysis of the influence of macroeconomic factors on long-term and short-term fluctuations of the Indonesian stock exchange (BEI) using the error correction method (ECM) approach. *Technium Soc. Sci. J.*, *63*, p.162.

Lehtola, T., & Zahedi, A. (2019). Solar energy and wind power supply supported by storage technology: A review. Sustainable Energy Technologies and Assessments, 35, 25-31.

Magweva, R., & Sibanda, M. (2020). Inflation and infrastructure sector returns in emerging markets—panel ARDL approach. Cogent Economics & Finance, 8(1), 1730078.

Maulidia, M., Dargusch, P., Ashworth, P., & Ardiansyah, F. (2019). Rethinking renewable energy targets and electricity sector reform in Indonesia: A private sector perspective. Renewable and Sustainable Energy Reviews, 101, 231-247.

Memarzadeh, G., Keynia, F., Amirteimoury, F., Memarzadeh, R., & Noori, H. (2025). A new hybrid intelligent method for accurate short-term electric power production forecasting from uncertain renewable energy resources. *International Journal of Industrial Electronics Control and Optimization*, 8(1), 45-55.

Migisha, A. G., Ntayi, J. M., Adaramola, M. S., Buyinza, F., Senyonga, L., & Abaliwano, J. (2024). Effects of technical and security factors on grid electricity reliability: evidence from Uganda national electricity grid network. Technological Sustainability, 3(1), 41-67.

Murshed, M. and Ozturk, I., 2023. Rethinking energy poverty reduction through improving electricity accessibility: A regional analysis on selected African nations. *Energy*, *267*, p.126547.

Musbah, H., Aly, H.H. and Little, T.A., 2023. A proposed novel adaptive DC technique for non-stationary data removal. *Heliyon*, *9*(3).

Obafemi, M. O. (2021). Determinants, Prevalence And Effects Of Electricity Theft Among Households In Lagos State (Doctoral Dissertation).

Ohaegbulem, E.U. and Iheaka, V.C., 2024. On remedying the presence of heteroscedasticity in a multiple linear regression model.

Olivares, K. G., Challu, C., Marcjasz, G., Weron, R., & Dubrawski, A. (2023). Neural basis expansion analysis with exogenous variables: Forecasting electricity prices with NBEATSx. International Journal of Forecasting, 39(2), 884-900.

Özdemir, Ö., Hobbs, B. F., van Hout, M., & Koutstaal, P. R. (2020). Capacity vs energy subsidies for promoting renewable investment: Benefits and costs for the EU power market. Energy Policy, 137, 111166.

Patel, N., Wang, Z., & Wei, S. J. (2019). Global value chains and effective exchange rates at the country-sector level. Journal of Money, Credit and Banking, 51, 7-42.

Paudel, A., Sampath, L. P. M. I., Yang, J., & Gooi, H. B. (2020). Peer-to-peer energy trading in the smart grid considering power losses and network fees. IEEE Transactions on Smart Grid, 11(6), 4727-4737.

Pérez, H. D. J. G., & Ortega, M. V. (2021). Mathematical economics in the explanation of economic growth in economies with endogenous and exogenous technological change. Revista Boletín Redipe, 10(5), 101-109.

Probst, B., Westermann, L., Anadón, L. D., & Kontoleon, A. (2021). Leveraging private investment to expand renewable power generation: evidence on financial additionality and productivity gains from Uganda. World Development, 140, 105347.

Razavi, R., & Fleury, M. (2019). Socio-economic predictors of electricity theft in developing countries: An Indian case study. Energy for Sustainable Development, 49, 1-10.

Ridzuan, A. R., Kamaluddin, M., Ismail, N. A., Razak, M. I. M., & Haron, N. F. (2020). Macroeconomic indicators for the electrical consumption demand model in Malaysia. International Journal of Energy Economics and Policy, 10(1), 16-22.

Roeger, W., & Welfens, P. J. (2022). Gas price caps and electricity production effects in the context of the Russo-Ukrainian War: modeling and new policy reforms. International Economics and Economic Policy, 19(4), 645-673.

Sadovskaia, K., Bogdanov, D., Honkapuro, S., & Breyer, C. (2019). Power transmission and distribution losses–A model based on available empirical data and future trends for all countries globally. International Journal of Electrical Power & Energy Systems, 107, 98-109.

Sam, C. Y., McNown, R., & Goh, S. K. (2019). An augmented autoregressive distributed lag bounds test for cointegration. *Economic Modelling, 80*, 130–141. https://doi.org/10.1016/j.econmod.2018.11.001

Saqib, A., Chan, T. H., Mikhaylov, A., & Lean, H. H. (2021). Are the responses of sectoral energy imports asymmetric to exchange rate volatilities in Pakistan? Evidence from the recent foreign exchange regime. Frontiers in Energy Research, 9, 614463.

Shapiro, A. H. (2022). How much do supply and demand drive inflation?. FRBSF Economic Letter, 15, 1-6.

Shen, W., Chen, X., Qiu, J., Hayward, J. A., Sayeef, S., Osman, P., ... & Dong, Z. Y. (2020). A comprehensive review of variable renewable energy levelized cost of electricity. Renewable and Sustainable Energy Reviews, 133, 110301.

Si, D. K., Li, X. L., & Huang, S. (2021). Financial deregulation and operational risks of energy enterprise: The shock of liberalization of bank lending rate in China. Energy Economics, 93, 105047.

Simionescu, M., Bilan, Y., Krajňáková, E., Streimikiene, D., & Gędek, S. (2019). Renewable energy in the electricity sector and GDP per capita in the European Union. Energies, 12(13), 2520.

Sridharan, V., Broad, O., Shivakumar, A., Howells, M., Boehlert, B., Groves, D. G., ... & Cervigni, R. (2019). Resilience of the Eastern African electricity sector to climate-driven changes in hydropower generation. Nature communications, 10(1), 302.

Sridharan, V., Shivakumar, A., Niet, T., Ramos, E. P., & Howells, M. (2020). Land, energy and water resource management and its impact on GHG emissions, electricity supply and food production- Insights from a Ugandan case study. Environmental Research Communications, 2(8), 085003.

Steinberg, D. C., Brown, M., Wiser, R., Donohoo-Vallett, P., Gagnon, P., Hamilton, A., ... & Prasanna, A. (2023). Evaluating impacts of the Inflation Reduction Act and the bipartisan infrastructure law on the US power system (No NREL/TP-6A20-85242). National Renewable Energy Laboratory (NREL), Golden, CO (United States).

Stern, D. I., Burke, P. J., & Bruns, S. B. (2019). The impact of electricity on economic development: A macroeconomic perspective.

Szustak, G., Dąbrowski, P., Gradoń, W., & Szewczyk, Ł. (2021). The relationship between energy production and GDP: Evidence from selected European economies. Energies, 15(1), 50.

Trotter, P. A., Cooper, N. J., & Wilson, P. R. (2019). A multi-criteria, long-term energy planning optimization model with integrated on-grid and off-grid electrification–The case of Uganda. Applied Energy, 243, 288-312.

Tudor, C., & Sova, R. (2021). On the impact of GDP per capita, carbon intensity and innovation for renewable energy consumption: worldwide evidence. Energies, 14(19), 6254.

Uganda Electricity Regulatory Authority. (2024). Minister's speech on the occasion to announce the 2024 electricity end-user tariffs.

Wabukala, B. M., Bergland, O., Rudaheranwa, N., Watundu, S., Adaramola, M. S., Ngoma, M., & Rwaheru, A. A. (2022). Unbundling barriers to electricity security in Uganda: A review. Energy strategy reviews, 44, 100984.

Wabukala, B. M., Mukisa, N., Watundu, S., Bergland, O., Rudaheranwa, N., & Adaramola, M. S. (2023). Impact of household electricity theft and unaffordability on electricity security: A case of Uganda. Energy Policy, 173, 113411.

Wang, J., Hassan, M. S., Alharthi, M., Arshed, N., Hanif, I., & Saeed, M. I. (2022). Inspecting non-linear behavior of aggregated and disaggregated renewable and non-renewable energy consumption on GDP per capita in Pakistan. Energy Strategy Reviews, 39, 100772.

World Bank. (2020). *Forecasting electricity demand: An aid for practitioners*. World Bank.