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Research Article

Determinants of Electricity Transmission and Distribution Losses in South Africa

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The increased electricity demand amidst inadequate electricity generation in South Africa has plunged the country into frequent power outages and load shedding. However, the country still has the lowest electricity transmission and distribution losses in sub-Saharan Africa. Despite low losses, there is still an opportunity to reduce losses further and reduce power outages and load shedding. This study examines the determinants of electricity transmission and distribution losses in South Africa. The results will inform policymakers on avoiding higher electricity transmission losses to alleviate the current electricity shortfall. Using the time-series data from 1971–2020 and the autoregressive distributed-lag (ARDL) bounds testing approach to cointegration, the study confirmed a long-run relationship between electricity transmission, distribution losses, and income, price, investment, political regime, and economic integration. Regression analysis from the ARDL methods revealed that investments, political administration, and economic integration positively influence electricity transmission and distribution losses. At the same time, income reduces electricity transmission and distribution losses in the long run. However, income, price, and economic integration minimize electricity transmission losses in the short run while the remaining variables maintained their positive effects. The implication is that without proper checks in place, an expansion in South Africa's economic integration, investment, and democracy may negatively affect the electricity sector of the country through an increase in electric power losses, while higher income will help the industry via lower electric power losses. The paper, among other things, recommends building a robust economy to ensure lower levels of electricity transmission and distribution losses.

1. Introduction

Electricity is the bedrock of economic development and growth [1, 2]. It offers numerous benefits to households and firms in the economy. At the household level, access to electricity enhances educational status, improves health outcomes, and empowers women, particularly in rural areas, who do not need to walk miles to find firewood for fuel and cooking. Economic activities such as manufacturing, mining, transportation, telecommunication, and worker productivity, essential ingredients for economic growth, depend on electricity. It is not strange that the literature has indicated a direct link between the level of economic development and reliable energy supply [3].

Therefore, it is disturbing that millions of people in developing countries cannot access electricity. For instance, although the number of people with access to electricity has improved in recent times in the sub-Saharan African region (SSA), there are about 600 million and 900 million people who, respectively, lack electricity and must walk long distances to find firewood for fuel and cooking [4]. The World Bank reported that countries in SSA experience annual outages ranging from 50 to 4,600 hours out of the 8,760 hours in a year [5]. The insufficient power generation capacity is due to archaic and inadequate energy infrastructure resulting from low investments and challenges in serving low-income users [6].

Low electricity access in SSA is a subject of much research [7, 8]. However, a significant void in the literature exists in studying electricity transmission and distribution losses. In SSA, the World Bank [9] states that electricity losses as a percentage of output attributed to transmission and distribution increased from 6.6% in 1986 to 11.7% in 2014. This figure compares unfavorably with other regions, including the Middle East, Eurasia, Asia, and Oceania. The high electricity losses affect the quality and quantity of electricity supply, the utility companies' profitability, and restrain new investment [8, 10]. Identifying the drivers of such electricity losses is crucial to policymakers and utility companies for better sector policies and management. This study sheds light on the factors that affect electricity losses in South Africa to inform the managers and policymakers.

South Africa has a robust energy sector in SSA, with more than 91% of citizens accessing electricity, allowing it to export electricity to neighboring countries [9]. However, over the past ten years, the country's electricity generation has not been able to meet the growing demand from industrialization and high accessibility [11]. This development has plunged the country into frequent power outages and load shedding. However, South Africa boasts the lowest electricity losses from transmission and distribution for over forty years in SSA. During this period, the highest losses were 10% in 2004, which declined to 8.4% in 2014 [9]. Several reasons are responsible for the low losses. A review of publications on the country's energy sector reveals that Eskom, the national utility company, prioritized maintenance, and refurbishment of the transmission and distribution network. Furthermore, Eskom installed smart prepaid meters to reduce electricity losses (https://www.get-invest.eu/market-information/south-africa/energy-sector/). The country's high economic growth may also have forced the government to invest in its energy infrastructure resulting in improved technical efficiency.

From the above, ensuring lower electricity losses are vital to building a robust energy sector for the country. Considering the current electricity shortfalls in South Africa, increased power losses will worsen the situation by reducing the quality and quantity of the electricity supply. The implication will be that many firms may not receive the required power supply for their productive activities, invariably restraining economic performance [1, 12]. Many households will experience diminished access to communication, healthcare, and academic services. In addition, higher electricity losses may severely depress the profitability of the utility companies and hinder new investment in the sector [8, 10]. The results of this study will have significant energy policy implications in South Africa to suffer lower electricity losses, maintain the current capacity, and avoid plunging the country into further crises.

Although various energy-related studies for the country, including an analysis of electricity/energy consumption factors [13–15] and energy intensity factors [11, 16] exist, studies on the drivers of electricity losses are nonexistent. The abovementioned situation requires econometric models that identify the drivers of electricity losses during transmission and distribution to supplement the descriptive analysis. In addition, existing studies on the drivers of electricity power losses [10, 17, 18]; and [19] have not analyzed the effect of economic integration on electricity power losses. While economic integration may facilitate the adoption of efficient technology for the electricity sector [20], it can increase electricity demand [21]. With supply constraints, theft may increase. In 1994, after the end of apartheid, South Africa became more integrated into the global economy [9]. For instance, its trading activities (trade as a percentage of GDP) with other countries increased from 38% in 1990 to 56% in 2021 [9]. This development may have caused the power sector's imbalance in electricity and demand because of the extra electricity needed to produce the excess goods and services [22], making controlling electricity losses necessary to maintain the existing capacity and avoid further load shedding. While governance matters in the energy sector and empirical studies have assessed the effect of various political/governance indicators on the energy sector [18] and especially electric power losses [10, 17]; and [19], little is known about the effect of a political regime on electricity losses. The end of apartheid saw the solidification of democracy as the county's political system.

Meanwhile, the literature remains inconclusive on the effect of democracy on resource management. Some researchers argue that democracy is associated with corruption, which precipitates poor resource management. Others say that democracy promotes the rule of law, freedom of speech and association, and media freedom, which help efficiently use economic resources [23, 24]. Allowing corruption to fester, adversely affects all sectors of the economy, including the electricity sector. Some also suggest that if an economy is under the leadership of a dictator, cronies, often with limited expertise, control the economic resources leading to waste and inefficiencies [25], much more than transparent democratic governance.

Another variable whose effect on electricity losses has received less empirical analysis is long-term capital investments [26]. Such investments improve the living conditions of citizens by increasing access to electricity [27]. However, some customers may resort to stealing power if the electricity is inadequate or not affordable during the capital recovery period. Although compared to other countries on the continent South Africa appears to have a higher amount devoted to capital investment, there has been a declining trend from US$ 86.39 bn in 2011 to US$ 53.62 bn in 2021 [9]. The repercussion of such a situation on electricity power losses for the country is unknown. This study investigates the impact of investments, political regime, and economic integration on electricity losses in South Africa, excluding income and price because their influence on electricity power losses is well documented (See Kwakwa [18]; Golden and Min [17]; Jamil [10]; and Mirza et al. [19]).

The study's findings will help fill the void in the literature [10, 17, 18] and [19]. The results may be necessary to other developing countries, especially those in the sub-Saharan African region, in designing the appropriate framework to address their electricity loss issues. The evidence shall also benefit South Africa by offering policymakers the needed information to improve the country's energy infrastructure efficiency. The paper proceeds in four main sections: Section 2 reviews the literature; Section 3 focuses on methodological issues; Section 4 presents and discusses results. The last section concludes the study and offers policy recommendations based on the findings.

2. Brief Literature Review

Researchers, policymakers, and governments have been keen on energy issues for many years because of their importance to economic growth and development. Energy is crucial in achieving the erstwhile Millennium Development Goals [28], the precursor to the United Nations Sustainable Development Goals (SDGs). In the Sustainable Development Goals, energy (SDG 7) features prominently--SDG 7 directly discusses energy issues. The remaining goals, especially climate action, clean water and sanitation, good health and well-being, and sustainable cities and communities, rely on energy to be realized. For this reason, there is a significant increase in empirical analyses on energy demand/consumption [8, 29], energy-saving/conservation [30], energy supply [8, 31, 32], and the environmental effects of energy consumption [29, 33, 34].

The supply side appears to be under-researched among the energy issues. Previous works have mentioned and identified various factors influencing energy supply. Carley [35] placed political institutions, natural resource endowments, income, electricity usage, price, and regional renewable portfolio standard as factors affecting renewable energy development in the USA. Aguirre and Ibikunle [36] found that renewable energy development is positively affected by carbon dioxide (CO_2) emissions, a signatory to the Kyoto Protocol, and biomass and solar potential. The use of coal, natural gas, and nuclear power in electricity generation tends to suppress renewable energy use. Liu et al. [37]; in their study on the Chinese energy supply, found that economic growth and energy prices significantly impact renewable energy development. Peprah [32] found that electricity supply in sub-Saharan African correlates positively with income, privatization, and labor. Kwakwa's [31] assessment of hydropower generation in Ghana reported that the country's hydropower generation is positively affected by trade openness, environmental degradation, alternate energy sources, and foreign direct investment. Kwakwa and Alhassan [38] found that price, technology, and ecological degradation positively affect hydropower generation in Ethiopia, but production costs hamper its production.

Very few studies incorporated energy losses in their energy supply analysis. These studies concluded that energy losses affect the level of electricity supply. Nababan [39] found that electricity, fuel prices, and energy losses influenced Indonesia's electricity supply. Akinyemi et al. [40] reported that electricity losses, technology, and investment adversely affected the energy supply, while income positively affected the electricity supply in Nigeria. In Ghana, Adom [8] also found that fuel costs, energy losses, and low prices negatively affected the electricity supply. Since energy losses affect the electricity supply level, researchers are beginning to pay attention to identifying the factors that influence electricity losses. The literature defines electricity losses as losses due to technical losses and nontechnical losses. Technical losses are losses in the generation, transmitting, and distributing of electricity through conductors and equipment [41, 42], while nontechnical losses are due to pilferage, unpaid bills, meter tampering, defective meters, errors in meter readings, and in estimating unmetered energy supply [42, 43]. It is thus "associated with the deceptive actions of consumers and officials of the supplying company as well as the state officials" ([18]: 8). Mimmi and Ecer [44] examined the effect of the number of rooms/occupants, precarious equipment, and business activities in the home that rely on electricity, energy-saving behavior, electricity consumption, and Brazil's tariff. Their econometric analysis reported that electricity theft increased by precarious equipment, electricity consumption, and the tariff. At the same time, the number of rooms and energy-saving behavior, including business activities, reduced it. A study by Golden and Min [17] sought to ascertain the underlying factors of electricity theft in Uttar Pradesh, India. Specifically, they assessed how political, geographical, sectoral, and technical characteristics affect power theft. Their estimation revealed that electioneering years and unmetered agricultural use positively affect the degree of electricity theft. In their study on power theft in Pakistan, Jamil and Ahmad [10] focused on the impact of income, chances of detecting theft, fines, temperature, electricity price, and load-shedding. The random-effects estimation technique revealed that the country's electricity theft is reduced by income but increased by fines, electricity price, load-shedding, temperature, and the probability of detection. In another study in Pakistan, Mirza et al. [19] found that price and the number of consumers buoy electricity theft while income and economic openness have a negative effect.

Gaur and Gupta [45] investigated India's electricity theft determinants. Their econometric analysis confirmed that determinants of power theft are both governmental and socio-economic. Precisely, poverty, urbanization, corruption, and electrified households increase electricity theft. In contrast, literacy, industry share, and private capacity reduce electricity theft. Kwakwa's [18] investigation on electricity losses in Ghana focused on the effects of capital investment, income, population, price, education, manufacturing, democratic periods of governance, and election years. Regression analysis confirmed education, electricity, investment, income, manufacturing, and population caused Ghana's electricity losses. He reported that investment, income, and education exert downward pressure on Ghana's electricity losses. However, population, manufacturing, and the price increased electricity losses. Jawad and Ayyash [46] also examined how the price of electricity, maintenance, number of customers, fines, prepaid meters, wages, education, and unemployment influenced electricity losses in Palestine. Their regression results showed that electricity loss is only significantly affected by the number of customers. The impact recorded was negative, and the authors argued that it could be due to the loyalty of new customers added to the grid lines. However, a Granger causality analysis showed that wages, fines, the number of customers, and prepaid meters cause electricity losses in the country.

The above review shows that energy issues have been examined empirically by researchers with different areas of attention, including energy demand, the environmental effect of energy, and energy supply [8, 33]. However, few empirical studies exist on electricity power losses despite their possible effect on economic activities. The extant studies have examined the issue using primary and secondary data and offering evidence from microlevel and macrolevel [18, 44]. Although the literature postulates that economic and noneconomic factors affect electricity losses, the direction of effects has been conflicting. Some variables have a positive impact in some studies and a negative effect in others. Moreover, there is a shortage of evidence on the impact of economic integration and political regime on electricity losses. This study is essential to help close this gap in the current literature.

3. Data and Methods

3.1. Empirical Specification. To explain electricity losses [18], one can conveniently rely on the possible causes of the technical and nontechnical losses, as argued in the literature, as the foundation for empirical studies of this nature. Both economic and noneconomic factors affect the level of a country's electricity losses. In the literature, economic factors such as income, employment, and price; and noneconomic factors, including location and political variables, have been argued to affect nontechnical losses. Additionally, improper load management, income, and large transformation stages are among the factors that influence technical electricity losses [10, 18, 47–50]. In this study, we analyze the effect of income, investment, price, and political regime on electricity losses in South Africa, and the electricity losses are specified in the following:

$$\text{EPL} = f\left(Y, P, \text{INV}, \text{POLI}, \text{EINT}\right), \tag{1}$$

where EPLC is electricity losses, Y is income, P is the price, and INV is the investment level. Also, POLI is a political regime and EINT is economic integration. Specifying the above equation into a Cobb-Douglas function gives

$$\text{EPL} = a.Y^{\varphi}.\text{INV}^{\sigma}.\text{EINT}^{\delta}.e^{P^{\phi}}.e^{\text{POLI}^{\lambda}}.\mu, \tag{2}$$

where EPL, Y, P, INV, POLI, and EINT remain, as explained earlier. The $\sigma, \gamma, \phi, \varphi, \mu$ and α are parameters to be estimated.

Taking the natural log of equation (2) gives

$$\begin{aligned}\ln\text{EPL}_t = {} & ɒ + \varphi\ln Y_t + \sigma\ln\text{INV}_t + \delta\ln\text{EINT}_t \\ & + \phi P_t + \lambda\text{POLI}_t + \nu_t.\end{aligned} \tag{3}$$

3.2. Data and Estimation Techniques. Except for the political regime data from the Polity IV Project (http://www.systemicpeace.org/polity/polity4.htm), all data used for this study comes from the World Bank [9]. Based on data availability, annual time-series data covering 1971–2020, however, the chosen study period is sufficient to offer helpful insight. The dependent variable, Electricity losses, is denoted by the electricity transmission and distribution losses (% of output)—it includes losses from the generation point to distribution to customers and pilferage. The study extrapolated the available data from 2014 to get values for the 2015–2020 periods, as suggested by works like Mohaddes and Raissi [51]. gross domestic product measures income, while investment represents gross capital formation. The political regime represented by Polity 2 measures the degree of autocracy and democracy in a country over the years. It ranges between −10 for autocracy and 10 for democracy, and the price is proxied by the consumer prices index. Table 1 presents the descriptive statistics of the variables over the study period. The electricity power losses over the period have a mean of 7.55%, a maximum value of 10%, and a minimum of 4.19%, illustrating that generally, South Africa has had a very low level of electrical power losses over the years. The means of income and investment are US$ US$ 206 billion and US$ 35 billion, respectively, revealing how vibrant the economy of South Africa has been over the period. The political regime has a mean of 6.8, showing that South Africa's governance has been more toward democracy than autocracy.

Time series analysis requires stationary variables to avoid getting spurious regression results. This study employs the popular Zivot-Andrews unit root test to assess the variables' stationarity properties. This test provides reliable results even when structural breaks exist in the series. In cases of structural breaks, the commonly used unit root tests like the Augmented Dickey–Fuller and Phillips–Perron tests cannot offer robust results. Even though time series variables may not be stationary, a long-run relationship is likely to exist among them. After the unit root test, the long-run relationship among the variables using the autoregressive distributed-lag (ARDL) bounds testing approach to cointegration is examined. The ARDL technique assesses the effects of income, investment, price, economic integration, and political regime on electricity losses in South Africa. The strength of the ARDL is that it is best for a mixture of variables integrated into orders 0 and 1, as found in this study. For robustness purposes, the FMOLS and the DOLS cointegration estimators are also employed to compare the results from the ARDL.

4. Results and Discussion

This section reports and discusses the results under the subsections, unit root and cointegration analysis, long-run regression analysis, and short-run regression analysis.

4.1. Unit Root and Cointegration Analysis. Since it is critical to ensure the analysis variables do not contain unit roots, the study used the Zivot-Andrews unit root test to assess the stationarity of the variables. The results in Table 2 show that the series is a mixture of $I(0)$ and $I(1)$ variables in structural breaks. Specifically, income, investment, price, economic integration, and electricity losses are stationary at the first difference, making them $I(1)$ variables. At the same time, the political regime is fixed at the level rendering it an $I(0)$ variable. This outcome indicates that the variables could be

Table 1: Descriptive statistic.

	EPL	TO	GDP	CPI	INV	POLI
Mean	7.551518	52.99419	$2.06E+11$	55.69834	$3.58E+10$	6.860000
Median	7.742570	53.45368	$1.80E+11$	44.98150	$2.83E+10$	9.000000
Maximum	10.00498	72.86539	$3.26E+11$	164.0516	$6.64E+10$	9.000000
Minimum	4.195117	37.48746	$1.09E+11$	2.486628	$1.90E+10$	4.000000
Jarque–Bera	2.723634	0.158708	4.861392	4.909900	6.883611	7.979810
Probability	0.256195	0.923713	0.087976	0.085867	0.032007	0.018501

used for the regression analysis without getting any spurious results. The study utilized the cointegration test to ascertain the long-run relationship between electricity losses and the selected explanatory variables. Table 3 shows the *ARDL* bounds testing *approach* used for this exercise. The results show that at a 5% level of significance, the F-statistic value is higher than the upper critical value, confirming cointegration. It also illustrates that income, price, investment, political regime, and economic integration could be behind the low electricity losses in South Africa.

Table 2: Zivot-Andrews unit root test results.

Series	At levels t-statistic (breakpoint)	At first difference t-statistic (breakpoint)
lnY	−3.6717 (2004)	−5.338** (1982)
lnINV	−3.928 (1984)	−6.4027*** (1994)
P	−3.3667 (1993)	−7.287*** (2007)
POLI	−10.0489*** (1992)	−4.6116** (1995)
lnEINT	−3.2604 (1982)	−6.1131*** (1994)
lnEPL	−4.7202 (1984)	−9.3225 (1987)***

Note. ***and **denotes 1, and 5% level of significance, respectively.

Table 3: Results of the ARDL cointegration test.

Series	Significance level (%)	I (0) bound	I (1) bound
	F-stat = 4.6050		
lnEPL|lnY,	10	2.26	3.35
P,lnINV,	5	2.62	3.79
POLI, lnEINT	1	3.41	4.68

4.2. Long-Run Regression Analyses. The estimations using data for the 1971–2020 periods from the ARDL, FMOLS, and DOL yield similar results and are reported in Table 4. The ARDL, the primary estimator in this work, shows that in the long run, the electricity losses in South Africa are significantly influenced by income, investment, inflation, political regime, and economic integration. On the direction of effect, income and inflation have a negative effect (although the latter is not statistically significant), while the remaining variables have a positive effect. Among all the variables, income has the largest impact on electricity losses; such that a 1% increase in the country's GDP level translates into about a 0.94% decrease in electricity losses. An increase in a country's GDP connotes three things: (a) an improvement in economic performance, (b) an increase in the wealth of the country, and (c) an improvement in the standard of living of the citizens. The first two variables can position the country to embark on the necessary technological investment in the energy sector, which reduces the electricity losses from the generation, transmission, and distribution processes. The third higher-income component enables citizens to avoid stealing electricity since they have the means to pay, explaining why a negative relationship exists between income and electricity losses in South Africa. As indicated earlier, South Africa is one of the leading economies among developing countries and a giant in SSA. The country's GDP expanded from US $ 203 billion in 2000 to 304 billion in 2020 [9], which could have enabled the country to invest in the energy sector to curtail any losses. This negative relationship between income and electricity losses supports previous findings [18, 19].

The results also reveal that electricity losses are positively affected by investment activities. Thus, a 1% increment in investment activities leads to a 0.46% increase in South Africa's electricity losses. The measure for investment in this study is not the investment made in the electricity sector, which was not available, but the total investment in the country. Eskom, the state-owned power utilities company, is responsible for over 95% of South Africa's electricity supply. In recent years, Eskom has imposed load-shedding on its electricity supply due to the underfunded, neglected, and poorly managed infrastructure, causing frequent breakdowns and operational inefficiencies. Though South Africa has been performing well economically, the electricity infrastructure remains in disrepair, causing electricity losses to go up from increased demand. Alternatively, the increase in electricity consumption could force some individuals to steal electricity, or meter installations may lag the pace of new building structures. It is not surprising that this finding differs from the work of Kwakwa [18]; which found a positive effect of investment on electricity losses where investments into the electricity sector were in areas that could help reduce electricity losses.

Economic integration increases electricity losses. The results show that in the long run, a 1% increment in the level of economic integration results in a 0.75% increase in electricity losses suggesting that the country's electricity power sector suffers to some extent due to economic integration. Though economic integration is not bad, we can deduce that economic integration puts pressure on electricity consumption because of the increased economic activities. Still, there needs to be adequate rehabilitation of the energy infrastructure to match the increased electricity needs. Indeed, previous studies, including Kwakwa et al.

Table 4: Long-run estimation results for 1971–2020.

Variable	ARDL results		DOLS results		FMOLS results	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
lnY	−0.9371***	0.2124	−0.6515***	0.2138	−0.7550***	0.2616
lnINV	0.4648***	0.1140	0.4569***	0.1470	0.5344***	0.1514
lnEINT	0.7451***	0.2230	0.8850***	0.2677	0.0395	0.2119
POLI	0.1055***	0.0138	0.0982***	0.0132	0.0618***	0.0145
P	−0.0002	0.0011	−0.0016	0.0013	0.0006	0.0013
C	11.5431**	4.8475	3.9898	4.8661	8.0784	5.5030

Note. ***and **denotes 1, and 5% level of significance, respectively.

Table 5: Long-run estimation results from 1971–2014.

Variables	ARDL		DOLS		FMOLS	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
lnY	−1.2244***	0.3084	−0.5640**	0.2695	−0.6814**	0.3173
lnINV	0.3948***	0.1359	0.5256***	0.1614	0.6394***	0.1673
P	0.0034	0.0030	−0.0038	0.0025	−0.0009	0.0028
POLI	0.1019***	0.0199	0.1099***	0.0168	0.0652***	0.0189
lnEINT	0.7187**	0.2736	0.9011***	0.2830	−0.0412	0.2214
C	20.8752**	7.7372	0.0199	6.8747	3.9998	7.8374

Note. ***and **denotes 1, and 5% level of significance, respectively.

[34]; Gyamfi et al. [52], and Aboagye [53], have argued that trade openness propels economic activities, which lead to the intensification of energy usage. Consequently, if economic integration of the South African economy causes demand for energy to exceed supply, some customers may steal electricity, yielding increased power losses.

Political regime records a positive coefficient denoting that as the economy becomes more democratic, the higher the electricity losses occur, and vice versa. The positive relationship is attributed to the fact that in democratic countries like South Africa, the punishment for consumers stealing electricity is more relaxed than in nondemocratic countries. Moreover, the pockets of corruption associated with democracy could also weaken the country's efforts to deal with technical and nontechnical electricity losses. This observation aligns with Gaur and Gupta [45]; who assert that politicians desirous of retaining power are more compromised and accept a bribe for cheaper electricity in exchange for a vote. As witnessed in South Africa, the political regime has not stamped out corruption, and many people in the top echelon of the government have faced corruption charges. Corruption may have weakened efforts to fight electricity power losses.

To ensure that the extrapolation of the dependent variable electricity transmission and distribution losses from 2015 to 2020 did not, influence the explanatory variables, the study compared the results of the regression analysis from 2015 to 2020, the extrapolated data, with the data from 1971 to 2014 period where the original data on electric power transmission and distribution losses was available. The long-run results reported in Table 5 do not differ much from those reported in Table 4.

4.3. Short-Run Regression Analysis. The results in Table 5 show that in the short run, income, investment, price, political regime, and economic integration influence the level of electricity losses in South Africa. The impact of income on electricity losses is negative, just as it was with the long-run results. A 1% increase in income leads to about a 2.732% decrease in electricity losses. The coefficient suggests the magnitude of impact in the short run is not different from that of the long run since they are both elastic. The conclusion is that income levels significantly affect short-term and long-term electricity losses. Investments affect electricity losses in the short run positively. Like its long-run effect, a 1% increase in the level of investment causes about a 0.50% increase in electricity losses. Another observation is that the type of political regime positively affects electricity losses in the country. A unit increase towards democracy causes electricity losses to increase by 0.20%. The positive outcome implies that the political regime maintains its positive effects in both short- and long-run periods. There are possible reasons behind the effect of income, political regime, and investment on electricity losses, as discussed in the following long-run results section in the following.

Increasing economic integration by 1% leads to about a 0.50% reduction in the level of electricity losses in the short-run, implying that in the short-run, opening to the global economy and allowing technological transfer into South Africa to occur improves the country's electricity sector. However, economic integration has a positive effect in the long run, attributed to the lack of attention to linking economic integration with electricity transmission and distribution efficiency. The price effect is negative, although not significant. The outcome may be because an increase in the general price tends to make people mindful of the financial implications when caught stealing electricity and, as a result, would lead to lower electricity losses. The coefficient of error correction term CointEq (−1) has a negative sign and is statistically significant at a 1% level of significance—confirming the established cointegration and the

Table 6: Short-run estimation results.

Variables	Coefficient	Std. error	Probability
D(lnY)	−2.7283***	0.9227	0.0056
D(lnINV)	0.4963***	0.1439	0.0015
D(lnEINT)	0.0738	0.2340	0.7543
D(lnEINT(−1))	−0.3514	0.2267	0.1304
D(lnEINT(−2))	−0.5008***	0.2264	0.0338
D(POLI)	0.1997***	0.0484	0.0002
D(P)	−0.0171	0.0114	0.1424
CointEq(−1)	−1.0677***	0.1642	0.0000

Note. ***and **denotes 1, and 5% level of significance, respectively.

Table 7: Short-run estimation results.

Variables	Coefficient	Std. error	Probability
D(lnY)	−1.1852***	0.3404	0.0017
D(lnINV)	0.3822**	0.1531	0.0190
D(P)	−0.0151	0.0161	0.3563
D(P(−1))	0.0617	0.0327	0.0698
D(P(−2))	−0.0368**	0.0175	0.0452
D(POLI)	0.1723***	0.0542	0.0037
D(lnEINT)	−0.2010	0.2442	0.4178
D(lnEINT(−1))	−0.3702	0.2789	0.1956
D(lnEINT(−2))	−0.6602**	0.2619	0.0179
CointEq(−1)	−0.9679***	0.1758	0.0000

Note. ***and **denotes 1, and 5% level of significance, respectively.

Table 8: Diagnostic tests results.

Diagnostic	Test	Probability
Serial correlation	Breusch–Godfrey, F-stat = 0.1625	0.8505
Normality	Jarque–Bera = 1.6784	0.4320
Heteroscedasticity	ARCH, F-stat = 0.0539	0.8170
Stability	Ramsey RESET, F-stat = 1.5599	0.2217

long-run relationship between electricity losses and the explanatory variables. The coefficient value of −1.06% indicates that the short-run losses adjust by 106% yearly towards the long run.

Again, the regression analysis results of the dependent variables, electricity transmission, and distribution losses from 2015 from 2020 and 1971–2014, showed that the extrapolation did not influence the explanatory variables. The short-run results reported in Table 7 do not differ much from those reported in Table 6.

The results were subjected to several critical diagnostic tests to ascertain the results' robustness and

Reliability. Table 8 shows the error terms from the ARDL estimation technique. These terms do not suffer from autocorrelation problems, heteroskedasticity, wrong specification, and non-normality—the results are reliable and robust.

5. Conclusion and Policy Options

A well-functioning electricity sector is crucial to economic growth, necessitating addressing issues affecting efficiency, such as electricity losses. This study investigated the drivers of electricity losses in South Africa, which has been faced with inadequate electricity generation to meet the growing demand—and reducing electricity losses would alleviate the electricity shortages. The study modeled electricity losses as a function of income, price, investment, economic integration, and political regime for the 1971–2020 period. Preliminary analysis of the data from the Zivot-Andrews unit root test revealed that except political authority, which was stationary at levels, the rest of the variables were static at first difference. Moreover, cointegration analysis confirmed a long-run relationship between electricity losses and income, price, investment, economic integration, and political regime type. The regression analysis shows that political regime and economic integration positively influence the level of electricity losses in the country in the long run.

In contrast, income exerts a negative effect on long-run investment. The short-run analysis also shows that electricity losses are reduced by income and economic integration while the other variables increase the electricity losses. In brief, the study has found that to avoid further deepening the energy crises of South Africa, authorities should focus on maintaining lower electricity losses by paying attention to income, economic integration, investment options, and democratic activities, as well as inflation. The above findings have some policy implications worth mentioning.

The level of investments in the economy and the economic integration positively influence the electricity losses in the network, resulting from dependence on the archaic energy infrastructure incapable of meeting the increasing electricity demand. Despite the government injecting substantial capital into the electricity infrastructure, little progress has occurred because of the excessive labor force, political influence, and dependence on old systems. South Africa should break Eskom into three distinct and independent companies to handle power generation, power transmission, and power distribution and allow the private sector to enter these markets. Admittedly, the power generation sector has allowed independent power producers to participate in the market. Still, the government must remove the barriers and increase incentives for more private-sector participation. The new entities formed should be allowed to operate independently. The government will also need to implement a program such as the feed-in tariff to ensure long-term power purchasing agreements to assure investors that they will have sufficient time to recapture their capital and capital return. Finally, the government should take over the loans from the former Eskom, which in any case were sovereignly guaranteed. Understandably, such action would precipitate apprehension about the downgrading of South Africa's credit rating for taking on so much debt. The government should create a special-purpose vehicle to hold the new entities' debt and shares. The loans can then be retired from taxing the new entities and other firms in the electricity sector. The taxes should be reasonable to incentivize investors to enter the market.

The above strategy will accomplish the following objectives. First, the new entities will have a clean balance sheet and focus on increasing operational efficiency and attracting private investments to rehabilitate the creaking infrastructure. Second, the government will have one shareholder seat in each entity. The company executives will pick qualified individuals to fill the other board seats based on need, not political connections. This approach will insulate these new entities from political influence, the source of current woes. Third, the electricity industry will be open to competition, a special ingredient to operational efficiency and competitive tariffs. Fourth, an electricity market will evolve, allowing firms and individuals to buy and sell electricity from anybody. Lastly, the availability of quality electricity will catalyze economic growth for the country's benefit and the neighboring countries that frequently import electricity from South Africa.

Data Availability

Data are available within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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