INTERNATIONAL JOURNAL OF SOCIAL SCIENCES BULLETIN
ISSN: (E) 3007-1917 (P) 3007-1909
Volume 4, Issue 3, 2026

ENERGY COSTS AND ECONOMIC PERFORMANCE: EVIDENCE FROM ELECTRICITY TARIFFS AND LOSSES IN PAKISTAN

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DOI: https://doi.org/10.5281/zenodo.20304252

Received	Accepted	Published
01 February 2026	17 March 2026	31 March 2026

ABSTRACT

The aim of this study to find the impact of real electricity tariffs and transmission losses on economic growth in Pakistan. The study uses annual time series data from 2001 to 2025 which has been collected from the website of National Electric Power Regulatory Authority (NEPRA) and World Development Indicator. Both short-run and long-run relationships among the variables are analyzed by using the Autoregressive Distributed Lag (ARDL) bounds testing technique. F-Statistics confirms the overall goodness of fit of the model and stationarity level of the data is analyzed by Augmented Dickey-Fuller (ADF) test. GDP growth is the dependent variable, while real electricity tariff, transmission losses, inflation, real interest rate, and exchange rate are the independent variables for the analysis. A long-run cointegrating relationship among the variables is the results. Transmission losses and real electricity tariff have a negative and significant impact on GDP growth. Inflation and real interest also negatively affect the economic growth. Policy recommendations include infrastructure investment for reducing transmission losses, introducing and implementing proper electricity tariffs, and sustaining macroeconomic stability and steadiness.

Keywords: *Electricity Tariff, Transmission Losses, GDP Growth, ARDL, Pakistan*

1. Introduction

Pakistan has confronted with continuous electricity sector difficulties and challenges in the last twenty years, such as significant transmission and distribution losses, as well as regular load shedding and power outages. These issues have significantly affected the economic growth of the country as electricity is essential for industrial manufacturing, business operations and residential use. The link between economic growth and energy sector has been widely studied globally, yet a specific detailed empirical investigation in this regard in Pakistan context is required because of the different structural challenges.

The electricity sector of Pakistan in struggling with significant circular debt issue, obsolete distribution and transmission lines and problems related to governance and management. Transmission and distribution losses have remained very high at approximately 20% of the total production of the sector which is well above the international standard of 6% to 8%. Conversely, the rates of the electricity have risen substantially in nominal value, but the real tariff have experience less drastic changes due inflationary factors. These elements have posed challenges for government and decision maker and also hinder the economic growth of the country.

This research aims to empirically analyze the effects of actual electricity tariff and transmission losses on GDP growth of Pakistan during the period from 2001 to 2025. The research incorporates the short-term dynamics and long-term equilibrium relationship through the use of the ARDL bound testing method. The results enhance the current literature by offering new empirical evidence and relevant policy insights for tackling the energy and economy nexus in Pakistan

2. Literature Review

The connection between energy supply and economic development has been widely discussed in the literature. The neoclassical growth model, articulated by Solow (1956) highlights capital accumulation and technological advancement as the key factors for economic growth, considering energy as intermediate input. Romer (1986) and Lucas (1988) studied significance of energy structure and supply in enhancement of productivity and technological advancement. The work of (Apergis & Payne, 2009) suggests that energy use, such as electricity, affects economic expansion, stating that inefficient energy can greatly curtail economic growth and performance.

To understand the relationship between electricity and economic growth, the idea of energy efficiency is very crucial. The study of (Patterson, 1996) indicates that productivity and competitiveness could be increased by achieving energy efficiency and enhancement through reducing transmission losses and executing efficient pricing. Adversely, increased energy costs and supply interruptions create production inefficiencies, reduce investment opportunities, and ultimately negatively affect the output growth. This study uses this theoretical foundation to investigate the effect on GDP by electricity tariff rates and transmission losses in Pakistan.

The study by Odhiambo (2009) in Tanzania discovered the linkage between electricity usage and economic growth by using cointegration and error correction models, their work revealed a one-way causality from electricity consumption to economic growth. Similarly, the work of Wolde-Rufael (2009) examined the relationship of energy consumption and economic growth in 17 African countries, and discovered mixed results among countries but generally supporting the view that electricity drives economic growth.

Mozumder and Marathe (2007) used vector error correction models to analyze the causal relationship between economic growth and electricity consumption in Bangladesh, and found a bidirectional causality. Energy usage positively affect economic expansion as the research of Sharama (2010) suggests, when they performed a panel analysis of Asia Pacific countries. Likewise, Paul and Bhattacharya (2004) studied the nexus of electricity usage and economic development in India, discovering cointegrated and bidirectional causality.

Khan et al. (2020) used nonlinear ARDL and discovered that positive shocks to energy consumption have a greater effect on growth compare the negative shocks, as their work analyzed the asymmetric effects of energy consumption on economic growth of Pakistan. Both renewable and nonrenewable energy consumption positively affect the economic growth of Pakistan, as found by the study of Rehman et al. (2021). A panel of South Asian nations studied by Abbas et al. (2022) to empirically validating the energy-led hypothesis, their work emphasizes that a stable and consistent energy supply is necessary precursor for sustained economic growth.

The study of Berndt & Wood (1975) discovered that high electricity prices increase production costs for industrial and commercial consumers, which may reduce output, employment opportunities, productivity and competitiveness. The increased electricity prices also reduce the disposal income of households, which may cause for reducing the consumption and overall demand for electricity. Conversely, higher tariffs could drive energy efficiency improvements and decrease expensive consumption.

Higher electricity tariffs increase production costs for industrial and commercial users, potentially reducing output, employment, and competitiveness (Berndt & Wood, 1975). For households, higher electricity prices reduce disposable income, potentially diminishing

consumption and aggregate demand. However, higher tariffs may also incentivize energy efficiency improvements and reduce wasteful consumption.
Rising energy prices provoked technological advancement and efficiency goals, which helped in reducing the negative production effects in Chinese industrial companies, Fisher-Vanden et al. (2004). A study on Barbados by Lorde et al. (2010) revealed that high electricity prices negatively impacted the economic growth in long-term. The high industrial electricity costs adversely affect the industrial production in Pakistan, Siddique (2004). Whereas, the study of Jamil and Ahmad (2010) also found that the rate of electricity significantly delayed the GDP growth.
A study by Lin and Wang (2019) regarding reforms in electricity pricing had distributional impacts on the industrial sector of China and discovered that these adversely affecting energy-intensive industries while favoring cleaner industries. Energy price shocks employ uneven influence on growth, whereby price hikes result in greater adverse effect compare to price decline, Shahbaz et al. (2020). Real electricity tariffs have a negative impact on industrial output in both the short term and long term in Pakistan as highlighted by the work of Hussain et al. (2021), their study investigated the connection between electricity prices and growth through quarterly data.
Transmission and distribution (T&D) losses serve as a significant indicator of inefficiency in electricity sector. Elevated T&D losses diminish the electricity that can be effectively utilized for productive purposes, raised the costs associated with the electricity supply, and worsen issues relating to circular debt (Emodi & Yusuf, 2015). In numerous developing nations, T&D losses surpass 15% to 20% of total generation, while the benchmark for developed countries ranges from 5% to 7%.
Erdoğdu (2011) investigated electricity distribution losses in Turkey, concluding that privatization aimed at reducing losses enhanced sector efficiency while indirectly impacting the economic growth. Al-Mulali and Binti (2011) examined electricity losses in a panel study in Middle Eastern countries discovering that these losses adversely influenced energy consumption and indirectly affected the economic growth. In the context of Pakistan Mahmood and Azam (2015) emphasized how T&D losses contribute to ongoing circular debt, limiting public investment and hindering growth.
Khan and Ahmad (2018) specifically investigated T &D losses and economic growth in Pakistan trough time series data, discovering a notable negative long-term relationship. They suggested that a one percent decline in T&D losses might boost GDP by 0.15 percentage point. Rehman and Zhang (2019) discovered that inefficiencies in the energy sector, such as T7D losses, contributed notably to lagging economic growth of Pakistan compared to its regional counterparts.

2.1 Literature Gap and Research Contribution

Even with the extensive research on energy and growth linkages, many gaps still exist. Most current research on Pakistan relies on data up to 2015-2018 and do not cover the post COVID period and recent rise in electricity prices. Secondly studied the impact of electricity tariff and transmission losses on GDP growth separately.
This research fills these gaps by utilizing data from 2001 to 2025, applying ARDL model that supports mixed integration orders, and incorporating essential macroeconomic control factors like inflation, interest rates, and exchange rates. This research adds to policy discussions by presenting new findings on the extent and importance of electricity sector effects on economic growth of Pakistan.

3. Research Questions and Objectives

3.1 Research Questions

1. Is there a long-term cointegrating connection among the real electricity tariff, line losses and GDP growth in Pakistan?
2. What is the importance of the effect of actual electricity prices on GDP growth in the short term and long term?
3. In what ways T & D losses impact economic growth in Pakistan?

4. What is the rate of adjustment to long-run equilibrium after a system shock?

3.2 Research Objectives

1. To analyze the long-term connection among real electricity tariffs, transmission losses, and GDP growth in Pakistan utilizing the ARDL bound testing method.
2. To gauge the short-term and long-term elasticities of GDP growth in relation to actual electricity tariffs and transmission losses.
3. To assess the error correction process and the rate of adjustment to reach equilibrium.
4. To offer policy suggestions rooted in evidence for enhancing efficiency in the electricity sector and its role in economic expansion?

3.3 Hypotheses

H_1: There is a long-term cointegrating relationship exists among real electricity tariffs, T&D losses, and GDP growth.
H_2: Real electricity rates have a considerable effect on GDP expansion.
H_3: Transmission losses substantially affect GDP growth.
H_4: The error correction term is significant and indicates a shift towards long-term equilibrium.

4. Methodology

4.1 Data and Variables

The data for this research that is yearly time series data spanning 25 years from 2001 to 2025, have been gathered from the websites of National Electric Power Regulatory Authority and the World Development Indicators. The variables are specified in the following manner:

Variable	Symbol	Definition
GDP Growth	GDPG	Annual growth rate of real GDP (%)
Transmission Losses	LOSSES	Electric power transmission and distribution losses (% of output)
Real Electricity Tariff	REAL_TARIFF	Nominal tariff deflated by GDP deflator (2016=100)
Inflation	INFLATION	GDP deflator (annual %)
Real Interest Rate	RIR	Real interest rate (%)
Exchange Rate	EXRATE	Official exchange rate (PKR/USD, period average)

The real electricity tariff was calculated as: Real Tariff = (Nominal Tariff ÷ GDP Deflator) × 100.

4.2 Descriptive Statistics and Correlation Analysis

Table 1: Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.
GDPG	3.99	4.07	7.83	-1.27	2.28
LOSSES	17.55	17.58	20.12	14.56	1.41
REAL_TARIFF	11.77	11.90	13.56	10.22	0.77
INFLATION	7.85	6.88	20.51	0.12	5.12
RIR	3.45	3.88	9.96	-6.18	3.89
EXRATE	85.44	85.17	288.16	32.79	63.78

Table 2: Correlation Matrix

Variable	GDPG	LOSSES	REAL_TARIFF
GDPG	1.000	0.312	0.083
LOSSES	0.312	1.000	-0.212
REAL_TARIFF	0.083	-0.212	1.000

The correlation matrix shows that GDPG has a weak positive correlation with LOSSES (0.31) and a very weak positive correlation with REAL_TARIFF (0.08) suggesting that multicollinearity is not a severe issue in the model.

4.3 Unit Root Tests

The Augmented Dickey-Fuller (ADF) test was performed to check the stationarity properties of the variables. The results are summarized below:

Table 3: ADF Unit Root Test Results

Variable	Level (Intercept)	First Difference (Intercept)	Order
GDPG	-3.668** (0.012)	-	I(0)
LOSSES	-1.475 (0.538)	-5.788* (0.000)	I(1)
REAL_TARIFF	-3.394** (0.022)	-	I(0)
INFLATION	-2.592 (0.102)	-3.398** (0.022)	I(1)
RIR	-2.245 (0.193)	-6.073* (0.000)	I(1)
EXRATE	-1.952 (0.306)	-11.712* (0.000)	I(2)*

Note: Exchange rate was stationary @ I(2) thus was excluded from the final ARDL model.

The unit root results indicate a mix of I(0) and I(1) stationarity of variables, which validates the use of the ARDL bounds testing approach. However, the exchange rate was found to be stationary at second difference [I(2)], and was therefore excluded from the final analysis.

4.4 ARDL Model Specification

The ARDL model for this study is specified as follows:

$$\Delta GDPG_t = \alpha_0 + \Sigma\ \alpha_1\Delta GDPG_{t-i} + \Sigma\ \alpha_2\Delta LOSSES_{t-i} + \Sigma\ \alpha_3\Delta REAL_TARIFF_{t-i} + \Sigma\ \alpha_4\Delta INFLATION_{t-i} + \Sigma\ \alpha_5\Delta RIR_{t-i} + \beta_1 GDPG_{t-1} + \beta_2 LOSSES_{t-1} + \beta_3 REAL_TARIFF_{t-1} + \beta_4 INFLATION_{t-1} + \beta_5 RIR_{t-1} + \varepsilon_t$$

The optimal lag length was selected using the Akaike Information Criterion (AIC). The bounds test was conducted to examine the presence of cointegration, with the null hypothesis of no long-run relationship (H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$) tested against the alternative.

5. Analysis and Results

5.1 ARDL Model Selection and Cointegration Test

Based on the AIC criterion, the ARDL(1,2,2,0,0) model was selected as optimal. The bounds test results are presented in Table 4.

Table 4: ARDL Bounds Test for Cointegration

Test Statistic	Value	Significance	I(0) Bound	I(1) Bound
F-statistic	5.575	10%	2.20	3.09
		5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

The calculated F-statistic (5.575) exceeds the upper bound critical value at the 1% significance level (4.37). Therefore, the null hypothesis of no cointegration is rejected, confirming the existence of a long-run relationship among the variables, GDPG, LOSSES, REAL_TARIFF, INFLATION, and RIR.

5.2 Long-Run Results

Table 5: Long-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	p-value
LOSSES	-0.238	0.125	-1.906	0.079
REAL_TARIFF	-1.636	1.016	-1.610	0.131
INFLATION	-0.198	0.103	-1.930	0.076
RIR	0.163	0.250	0.651	0.527
C	20.300	11.364	1.786	0.097

The long-run results indicate that transmission losses (LOSSES) with a coefficient of -0.238 shows a negative impact on GDP growth. This suggests that a one percentage point increase in transmission losses reduces GDP growth by approximately 0.24 percentage points in the long run. The coefficient is significant at the 10% level. Real electricity tariffs (REAL_TARIFF) also show a negative relationship with GDP growth (coefficient = -1.636), indicating that higher real electricity prices constrain economic growth.

The negative coefficient (-0.198) of Inflation (INFLATION) shows an adverse impact on GDP growth at 10% significant level, indicating that price volatility hampers economic growth and performance. The real interest rate (RIR) is statistically insignificant as it has a positive coefficient.

5.3 Short-Run Results and Error Correction Model

Table 6: Error Correction Model Results

Variable	Coefficient	Std. Error	t-Statistic	p-value
ΔGDPG(-1)	-0.326	0.151	-2.157	0.043
ΔLOSSES	0.092	0.257	0.359	0.725
ΔLOSSES(-1)	-0.417	0.229	-1.823	0.091
ΔREAL_TARIFF	-0.316	0.729	-0.434	0.671
ΔREAL_TARIFF(-1)	0.967	0.769	1.257	0.231
ΔINFLATION	-0.223	0.103	-2.158	0.050
ΔRIR	0.183	0.298	0.615	0.549
ECT(-1)	-0.671	0.089	-7.551	0.000

The negative coefficient (-0.671) of error correction term (ECT(-1)) is statistically significant at the 1% level. This suggests that approximately 67% inequity caused by last year's shock is rectified in current year, this indicates an immediate move towards long-term equilibrium.

GDP growth is positively affected by its own previous value in short run, having a coefficient of -0.326 (significant at the 5% level). The negative coefficient (-0.223, p = 0.050) of inflation (ΔINFLATION) shows a significant adverse effect on GDP growth. The negative coefficient (-0.417) of transmission losses (ΔLOSSES(-1)) at significant at the 10% level, suggests that variations in losses affect short-run growth.

5.4 Diagnostic Tests

Table 7: Diagnostic Test Results

Test	Statistic	p-value	Conclusion
Breusch-Godfrey LM Test (Serial Correlation)	F(2,11)=0.236	0.794	No serial correlation
Breusch-Pagan-Godfrey (Heteroskedasticity)	F(16,3)=0.278	0.963	Homoskedasticity
Jarque-Bera (Normality)	1.234	0.539	Residuals are normal

CUSUM Test	Within 5% bounds	-	Stable parameters

The model is appropriately specified and good fit as the results of diagnostic tests verify. Breusch-Pagan-Godfrey confirmed the Homoskedasticity and there are no signs of serial correlation. The Jarque-Bera confirmed the normality of residuals, and the parameter stability is maintained throughout the sample period as verified by the CUSUM test.

6. Discussion of Findings

The empirical conclusions offer several key findings. The confirmation of cointegration among the variables supports the long-term connection between electricity sector variables and economic growth in Pakistan. this corresponds with the results of Khan and Jamil (2018) and Rehman and Zhang (2019) regarding Pakistan, as well as with the wider literature on the energy-growth relationship.

Additionally, the adverse and substantial effect of transmission losses on GDP growth holds economic significance. The coefficient of -0.238 indicates that Pakistan's consistently elevated T&D losses (hovering around17% to 20%) decreases annual GDP growth by 4 to 4.5 percentage points.

Moreover, the weak negative correlation between the real tariff and GDP growth indicates that the inflationary forces have significantly countered nominal tariff hike, restricting the the real price signal to consumer and businesses. Nonetheless, the negative value of the coefficient aligns with economic theory and earlier empirical results.

The substantial adverse effect of inflation on GDP growth underscores the necessity of macroeconomic stability for achieving growth. This result aligns with Barro (1991) and various cross-country research indicating that inflation exceeding moderate levels negatively affects economic performance.

The error correction term of -0.671 indicate robust adjustment dynamics, suggesting that shocks in electricity sector have effects on GDP growth that are relatively temporary. This swift adaptation mirrors the capacity of businesses and households to respond to change in electricity prices and availability by implementing strategies like enhancing energy efficiency or decreasing demand

7. Conclusion and Policy Recommendations

7.1 Conclusion

This research analyzed yearly data from 2001 to 2025 by applying ARDL bound testing methodology to investigate the effects of real electricity tariff and transmission losses on the economic growth of Pakistan.

After the analysis of 25 years data, the results discovered that there is long-term cointegrating relationship among GDP growth transmission losses, real electricity tariff, inflation, and real interest rate in Pakistan throughout the period of analysis.

The analysis revealed that the transmission losses negatively and significantly affect GDP growth in both the short and long term, lowering the growth rate.

The results also suggest that the real electricity tariffs also have a adverse impact on GDP growth, although this effect is not statistically significant at standard levels.

The study also discovered that inflation negatively affects GDP growth, emphasizing the importance of maintaining price stability in the economy.

The results of error correction term is negative and meaningful and indicate a move towards long-run equilibrium, which suggests that around 67% of the imbalance is rectified within the period of one year.

The results of the study indicate that inefficiencies in the electricity sector especially transmission losses highly affect the economic growth of Pakistan. The findings of the analysis suggest that there is a need for prompt and attainable reforms in the electricity sector to achieve efficiency and foster sustainable economic growth in the country.

7.2 Policy Recommendations

1. Minimize Transmission and Distribution Losses:

Transmission and distribution losses are very high and occurred due to outdated infrastructure. authorities must prioritize the investment in transmission system, which includes modernizing outdated transformers and transmission system, upgrading old lines and implementing smart grid technologies. A reduction in T&D losses from their current level (17-20%) to 10-12% may lead and help to enhance the GDP growth by 1.5-2 percentage points each year.

2. Rationalize Electricity Tariffs:
Implementation of proper tariff also play a vital role in economic growth. The nominal tariffs of electricity have risen significantly, and the real tariff have stayed comparatively consistent due inflationary effect. The government should to establish a cost-based tariff system that aligns fiscal sustainability with affordability concerns for the consumers. Industrial production is very important for export competitiveness, Cross-subsidies need to be adjusted to prevent imposing undue cost on industrial consumers.

3. Enhance Macroeconomic Stability:
Microeconomic stability plays a vital role in economic development. The opposing effect of inflation on growth highlights the necessity for sensible monetary and fiscal measures. The State Bank of Pakistan need to prioritize and promote price stability, whereas fiscal authorities should make policies to decrease borrowing from the banking sector to reduce inflationary pressure.

4. Tackle Circular Debt:
The electricity sector faces an increasing and regular problem of circular debt which negatively effects its performance. This issue must be addressed by applying a mix of tariff adjustments, enhancement in efficiency, reforms in governance and management. Reduction in T&D losses will directly reduce circular debt by narrowing the difference between expenses and collection.

5. Promote Energy Efficiency:
Energy efficiency also plays a vital role in enhancing the performance of the sector and in achieving economic growth. Policies should be made by the authorities for broadening the energy efficiency for industrial and domestic users. These include labeling initiatives, performance targets, and funding solutions for efficiency improvements.

6. Broaden Energy Options:
The government should focus on renewable sources of energy which is cost effective. Proper and high investment in renewable sources can reduce the average electricity generation cost. Thus, energy security and efficiency can by achieved and also helps in reduction the vulnerability of the economy to fluctuations in imported fuel prices.

7.3 Limitations and Future Research
This research relies on overall GDP growth, a breakdown to different sectors like agriculture, manufacturing, services could yield more detailed sector wise insights. The limited sample size is another limitation of the study which restricts the number of lags that can be added. Further studies considering larger period of time series or more frequent data could enhance these evaluations more.

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