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Investigating the Linkage between Economic Growth, Electricity Access, Energy Use, and Population Growth in Pakistan

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Abstract: Electricity is a versatile form of energy that plays a vital role in fulfilling the daily requirements of human life. The primary aim of this study was to investigate and explore the link between economic growth, electricity access, energy use, and population growth in Pakistan for the period 1990–2016. An autoregressive distributed lag (ARDL) bounds testing approach to cointegration was applied to investigate the causality link between the study variables. These tests shed light on the long-run connection among the variables; further, the results revealed that the electricity access to the total population, electricity access to the urban population, energy usage, population growth, and urban population growth had a significant impact on economic growth, while the electricity access to the rural population and rural population growth had a negative impact on the economic growth in Pakistan. According to these findings, this study recommends that the government of Pakistan pay further attention to increasing its electricity production from different sources, including hydroelectric, solar, oil, and gas, and nuclear in order to fulfill the country's demands.

Keywords: economic growth; electricity access; energy production; population growth; ARDL

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1. Introduction

Energy plays a dominant role in the economic development and is also a fundamental part of any nation's economy. It relates to energy security, economic development, and social stability. Electricity possesses vital value, and is considered the source of energy that supports every aspect of the economy [1–4]. Over the past few decades, policy failures in the energy sector of Pakistan plunged the country into a severe power crisis, leading to the poor economic performance of the country. The demand of electricity is determined by the population growth as well as other factors, including electricity prices, people's migration to cities, and the weather. However, Pakistan's unique problems and the transformation of the electricity shortage and crisis are caused by theft, abuse, and the excessive usage of electricity in the industrial sectors and homes, unreasonably causing huge line losses, corruption, mismanagement, institutional weakness, and political controversy [5]. In 2011, the population growth in Pakistan was 176.17 million as compared to 79.98 million in 1980, and the growing population's demands are increasing, which directly affects the electricity escalation [6].

The South Asian Region (SAR) faces several deficiencies that affect the national system of electricity for a particular time. The electricity supply has not kept stride with the relevant growth and demand, resulting in a long-term downtime and frequent unplanned outages. These conditions have created difficulties for families and industries, and have hampered new investment in the business of any economy [7–10]. Pakistan has a population of about 184 million people, and the rural population that is associated with agriculture is high. The agricultural sector has contributed about 25% of the gross domestic product (GDP), and provides employment for more than 40% of the labor force [11]. The installed power generation in 2011 was 21,036 megawatts. The demand of electricity is increasing by about 9% a year, while the supply is only about 7%, and the gap in the summer is even greater [12,13]. Electricity generation sources in Pakistan include thermal energy (natural gas and oil), nuclear power, and hydropower. Renewable energy and coal are currently playing a secondary role, but are hoped to be boosted significantly in the coming decades [14]. The identified energy renewable resources are primarily solar energy, wind energy, and biomass. Hydropower, thermal, and nuclear power plants are a part of the hybrid industry in Pakistan. About 31% of electricity is produced by hydropower systems, 66.8% are produced by thermal systems, and the remaining 2.2% are produced by nuclear power. Further, the country imports 29.4% of its natural gas, 37.8% of its oil, 29.4% of its hydropower, and 0.26% of its natural gas in order to meet its energy needs. Coal and nuclear power have limited contributions to their energy supply, at 0.1% and 3.02%, respectively [15].

Currently, in Pakistan, the energy demand is of an average of 17,000 megawatts, while the shortage is of about 4000–5000 megawatts. In the coming years, the energy demand will increase further by approximately 500 megawatts in the next 10 years [16]. The electricity shortage reached 5500 megawatts in 2015, and the supply was 15,500 megawatts, with 23,000 megawatts of the installed capacity. The demand will rise in different sectors, including construction, agriculture, education, manufacturing, and most importantly, in sustainable development in order to boost the economic sector [17]. During the period of 2014–2015, the total electricity generation was 109,059 GWh, of which nearly two-thirds came from the thermal sources [18]. The electricity demand in Pakistan is driven by several issues, such as the rapidly growing population, electricity prices, economic expansion, urban resident flows, and weather. However, the major, specific problems of the country are the crisis that led to electricity shortages, which were caused by theft and the excessive use of electricity in domestic and industrial sectors, resulting in a huge loss of power lines and mismanagement and political controversy in mega-power projects [19]. Pakistan suffers from energy shortage due to production and supply. The major objective of this study was to explore and investigate the relationships between economic growth, electricity access to the total population, electricity access to the rural population, electricity access to the urban population, rural and urban population growth, total population growth, and energy usage in Pakistan. Time-span data was used in this study, which was collected from the World Development Indicators (WDI). We employed the Augmented Dickey–Fuller unit root test and Phillips–Perron unit root test to check the stationarity of the variables. The autoregressive distributed lag (ARDL) bounds testing approach to cointegration and the analysis of the long-run and short-run was used to gauge the dynamics causality among the study variables. Apart from the introduction section, the remaining paper has been organized as follows. Section 2 presents the existing literature regarding electricity production. Section 3 is the materials and methods section, which presents the data sources and model specification. Section 4 represents the empirical estimation strategy, and Section 5 is the results and discussion section that illustrates the results of the unit root tests, the results of the cointegration test, long-run and short-run results. Section 6 is conclusion and policy recommendation.

2. Existing Literature

The energy sector of any country plays a vital role in economic growth and development. Energy shortage in Pakistan has hampered the country, and caused severe crisis in the last several decades. The electricity sector received a great deal of attention due to rapid growth in the demand. Similarly, other factors, including inadequate water supply, water pollution, air pollution, and pasture degradation, are chief challenges that the country is facing [20]. Electricity, as a form of energy, plays an important role in boosting the economic growth of a country, and includes all of the sectors. Life quality and social well-being can improve with the severe production of sustainable electricity [21]. The total installed electricity capacity was 24,823 megawatts in 2015, with a maximum demand of

26,437 megawatts [22]. In response to this severe power shortage, long-term debates regarding energy production occurred, and participation in energy summits discovered a panacea in order to compensate for the shortage of electricity. Numerous conceivable regenerative and renewable electricity production sources are presently being deliberated upon, with suggestions for a short-term, medium-term, and long-term solutions to this trouble [23].

The supply of electricity in the rural communities contributes to economic growth, leading to improvements in agriculture, education, health, gender equality, and sustainable development [24,25]. Outdated equipment, improperly installed capacity, an inability to operate transmission systems, and deprived monetary administration are the main reasons behind the failure of the electricity sector in Pakistan [26,27]. The shortage is due to the lack of political instability and large investment, which has hindered the hydropower or coal projects, thereby increasing the dependence on imported expensive fuels and plummeting the local natural gas [28]. The country's growing population, industrialization, and average household income have contributed to the growth in the demand for electricity [29]. Social and economic progress depends on energy flow. Currently, the country is producing insufficient energy and thus is facing a crisis. Despite renewable energy sources, traditional energy generation methods are still being used in Pakistan. In the present period, energy efficiency has amplified, but the energy generation systems have not been updated to fulfill the energy requirements [30,31]. The electricity deficit in 2013 was of 6000 megawatts (MW), which is more than the usual 4000–5000 megawatts per year, and the gross domestic product (GDP) declined by 3–4% due to the energy crisis. The crisis has seriously affected the economy of Pakistan as a result of industry closures [32,33].

Electricity is an important component of the infrastructure for a country's socioeconomic development, and it represents a robust correlation between the consumption of electricity and economic growth [34]; however, growth in electricity production is extremely sensitive to local differences and domestic income levels [35]. The traditional electricity generation systems typically rely on a large quantity of power generation equipment. Considering the great size, it should be placed in a suitable geographic location. The generated electricity will be delivered to the grid station through heavy-duty transmission lines, and then be transmitted from the grid station to the users. These sources belong to renewable sources, including solar, hydro, and wind [36].

Pakistan ranks high in the world in terms of agricultural and industrial products, but energy problems still exist in the country due to a lack of sufficient measures by the government. However, the primary cause is associated with the government management measures, and Pakistan is also facing a severe energy crisis due to geopolitical uproar and a lack of interest [37–39]. Electricity is a key source of energy in the agricultural and industrial sector; it contributes almost 50% of Pakistan's economy. The industrial, commercial, and agricultural sectors consume about 27.7%, 7.5%, and 12.5% of the nation's consumption of electricity, respectively [40,41]. In order to produce adequate, inexpensive, and environmentally-friendly energy and establish alternative combinations and existing renewables sources of energy, the relevant necessary steps require implementation. Numerous authors have suggested that developing and developed countries should use renewable energy sources such as alternative and sustainable energy over conventional energy sources [42–51].

Furthermore, various studies have been conducted in order to highlight the relationship between energy consumption, electricity consumption, CO_2 emissions, employment, real income, residential demand for electricity, exports, GDP, and economic growth by employing cointegration approaches and Granger causality tests [52–62]. However, the key motive of this study is to analyze the link between economic growth, electricity access to rural population, electricity access to urban population, electricity access to total population, rural and urban population growth, total population growth, and energy usage in Pakistan. Pakistan is located in South Asia, and most of the population living in rural areas is not linked to the power grid. The key component of rural grid electrification simply does not exist. The reason behind this is that certain rural areas have complex geography, moderately low electricity demand, and a huge cost of long delivery systems. Furthermore, there is a daily shortage of electricity in rural areas connected to the grid, mainly during the summertime.

3. Materials and Methods

3.1. Data Source

Time span data from 1990–2016 was used in this study, which was collected from the WDI (World Development Indicators). Below, Table 1 represents the variables used in this study:

Table 1. Description of Variables and Data Sources. WDI: World Development Indicators.

Variables	Explanation	Data Sources
GDPPC	Gross Domestic Product Per Capita	WDI
EAP	Electricity Access to Population	WDI
EARP	Electricity Access to Rural Population	WDI
EAUP	Electricity Access to Urban Population	WDI
EN	Energy Use	WDI
PG	Population Growth	WDI
RPG	Rural Population Growth	WDI
UPG	Urban Population Growth	WDI

Note: the units of the variables are in USD and %.

The electricity access of the total population, electricity access of the rural population, electricity access of the urban population, energy usage, population growth, and rural and urban population growth from 1990–2016 is illustrated in Figures 1–8, and data was taken from the WDI (World Development Indicators).

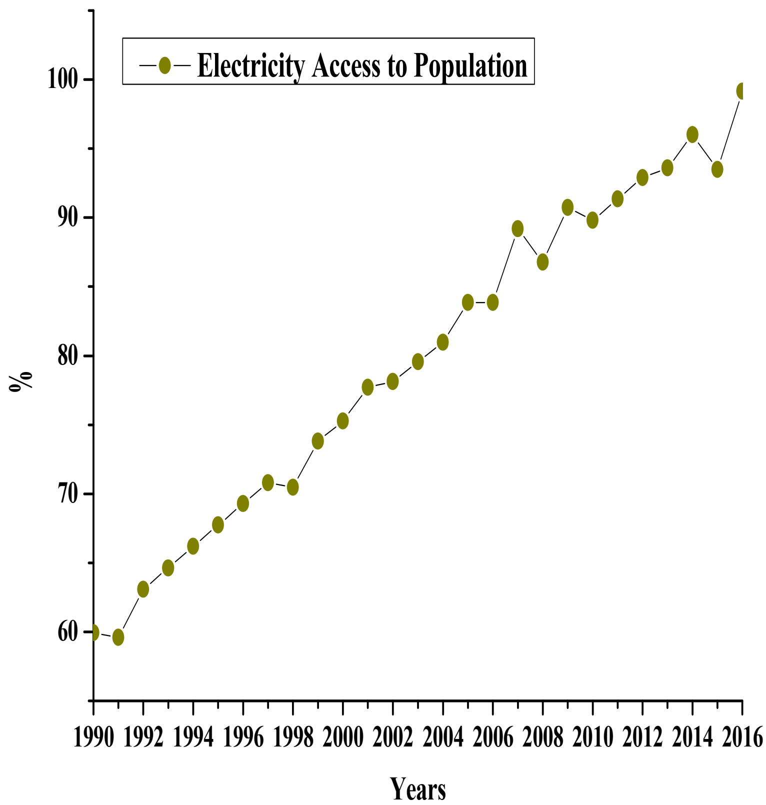

Figure 1. Electricity Access to the Total Population.

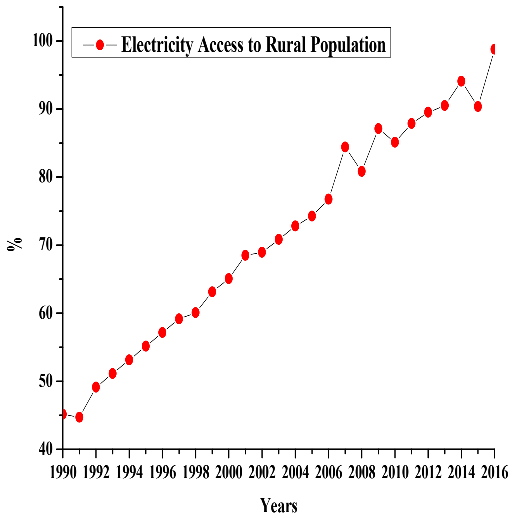

Figure 2. Electricity Access to the Rural Population.

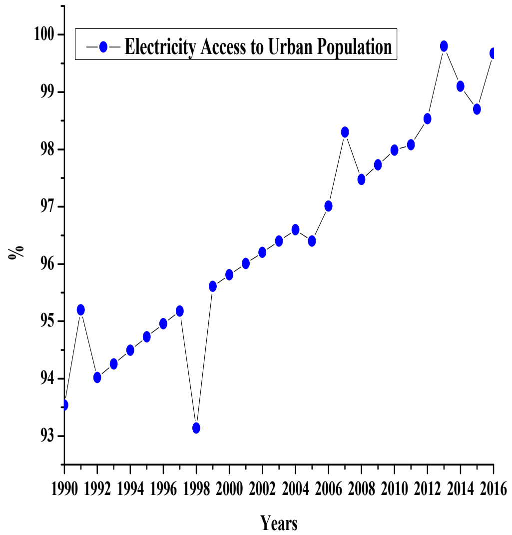

Figure 3. Electricity Access to the Urban Population.

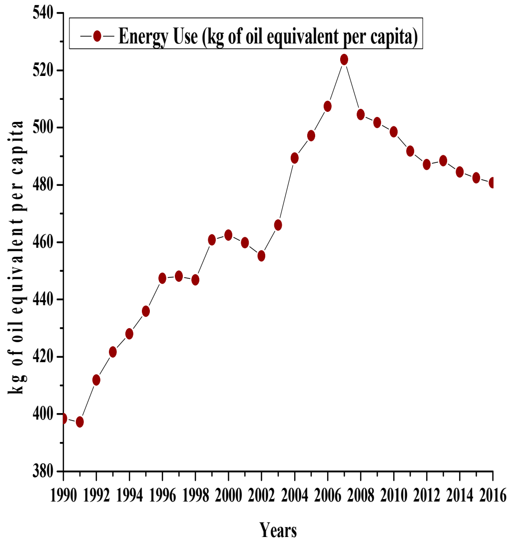

Figure 4. Energy Use in Pakistan.

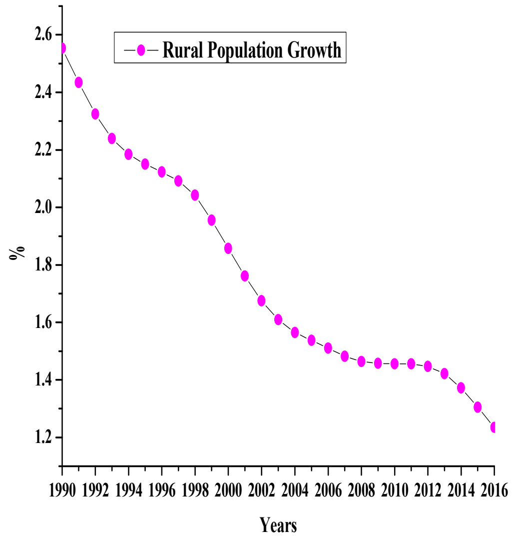

Figure 5. Rural Population Growth in Pakistan.

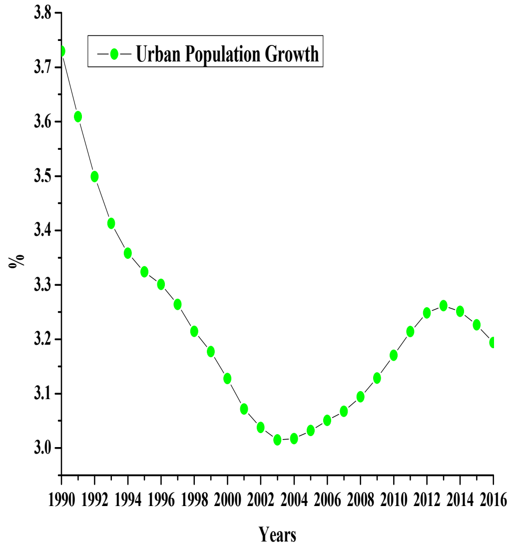

Figure 6. Urban Population Growth in Pakistan.

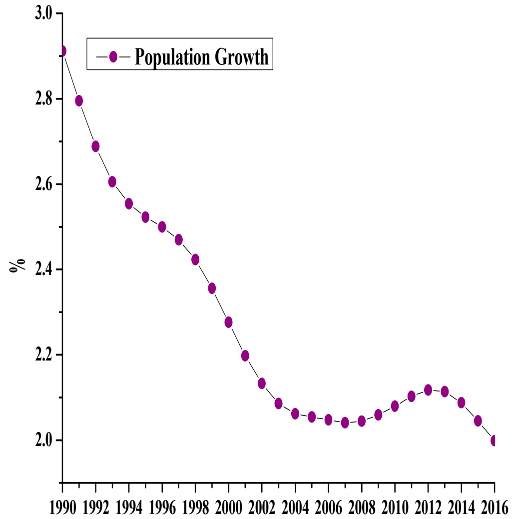

Figure 7. Population Growth in Pakistan.

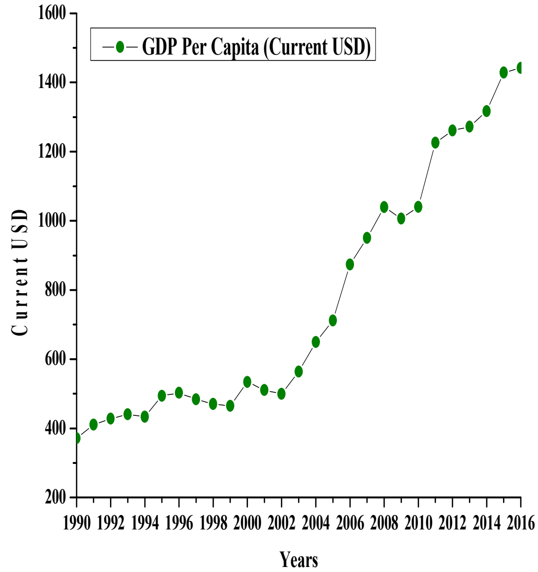

Figure 8. Gross Domestic Product (GDP) Per Capita in Pakistan.

Figures 1–8 represents the electricity access to the total population, electricity access to the rural population, electricity access to the urban population, energy usage, population growth, and rural and urban population growth, respectively.

3.2. Model Specification

To check the association among dependent and independent variables, the model follows the Fatai (2014) [63] specification to adopt the regression procedure. The multivariate regression model specification is as follows in its implicit forms as:

$$\mathrm{GDPPC_t} = \mathrm{f}(\mathrm{EAP_t}, \mathrm{EARP_t}, \mathrm{EAUP_t}, \mathrm{EN_t}, \mathrm{PG_t}, \mathrm{RPG_t}, \mathrm{UPG_t}) \tag{1}$$

In Equation (1), $\mathrm{GDPPC_t}$ indicates the gross domestic product per capita, $\mathrm{EAP_t}$ represents the electricity access to the total population, $\mathrm{EARP_t}$ indicates the electricity access to the rural population, $\mathrm{EAUP_t}$ represents the electricity access to the urban population, $\mathrm{EN_t}$ indicates the energy use, $\mathrm{PG_t}$ show the population growth in Pakistan, $\mathrm{RPG_t}$ represent the rural population growth, and $\mathrm{UPG_t}$ indicates the urban population growth.

$$\mathrm{GDPPC_t} = \Psi_0 + \Psi_1\mathrm{EAP_t} + \Psi_2\mathrm{EARP_t} + \Psi_3\mathrm{EAUP_t} + \Psi_4\mathrm{EN_t} + \Psi_5\mathrm{PG_t} + \Psi_6\mathrm{RPG_t} + \Psi_7\mathrm{UPG_t} + \mu_t \tag{2}$$

By using natural logarithm to Equation (2), a log-linear model is as follows:

$$\mathrm{lnGDPPC_t} = \Psi_0 + \Psi_1\mathrm{lnEAP_t} + \Psi_2\mathrm{lnEARP_t} + \Psi_3\mathrm{lnEAUP_t} + \Psi_4\mathrm{lnEN_t} + \Psi_5\mathrm{lnPG_t} + \Psi_6\mathrm{lnRPG_t} + \Psi_7\mathrm{lnUPG_t} + \mu_t \tag{3}$$

Equation (3) presents the log-linear form of the variables. $\mathrm{lnGDPPC_t}$ represents the natural logarithm of the gross domestic product per capita; $\mathrm{lnEAP_t}$ represents the natural logarithm of electricity access to the total population; $\mathrm{lnEARP_t}$ represents the natural logarithm of the electricity access to the rural population; $\mathrm{lnEAUP_t}$ represents the natural logarithm of the electricity access to the urban population; $\mathrm{lnEN_t}$ represents the natural logarithm of energy use; $\mathrm{lnPG_t}$ represents the natural logarithm of population growth in Pakistan; $\mathrm{lnRPG_t}$ represents the natural logarithm of rural population growth; $\mathrm{lnUPG_t}$ represents the natural logarithm of urban population growth; t is the time dimension; μ_t is the error term; Ψ_0 indicates the constant intercept; and the coefficients of the model Ψ_1 to Ψ_7 represent the elasticity for the longrun.

4. Empirical Estimation Strategy

4.1. Unit Root Test for Stationarity

Despite the fact that the autoregressive distributed lag (ARDL) model requires no pre-testing for inspection of variables stationarity through the unit root test. The Augmented Dickey–Fuller (1979) [64] unit root test and Phillips–Perron (1988) [65] unit root test with trend and intercept was used to determine that none of the variables considered were integrated to order two. This is because the ARDL bounds testing approach is invalidated in cases where I(2) variables are used. Therefore, the unit root test was performed using Equation (3):

$$\Delta Z_t = \alpha_0 + \beta_0 T + \beta_1 Z_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta Z_{t-1} + \mu_t \tag{4}$$

where Z indicates the variables being tested for the unit root, T represents a linear trend, Δ indicates the first difference, t shows the time, μ_t is the error term, and m represents achieving white noise residuals.

4.2. Cointegration with ARDL Model

Pesaran and Shin (1998) [66] developed the ARDL bounds testing approach to check the analysis of long-run and short-run relationships, which was further protracted by Pesaran et al. (2001) [67], and Narayan et al. (2004) [68]. The cointegration testing approach is applicable regardless of the integration order with concerned variables, I(0) and or I(1), except for the occurrence of I(2). The long-run and short-run relations examined the ARDL representation of the unrestricted error correction model (UECM) of Equation (2), as depicted in Equation (5):

$$\begin{aligned} \Delta \mathrm{lnGDPPC}_t = \gamma_0 \; & + \sum_{i=1}^{P} \gamma_{1i} \Delta \mathrm{lnGDPPC}_{t-i} + \sum_{i=1}^{q^1} \gamma_{2i} \Delta \mathrm{lnEAP}_{t-i} + \sum_{i=1}^{q^2} \gamma_{3i} \Delta \mathrm{lnEARP}_{t-i} \\ & + \sum_{i=1}^{q^3} \gamma_{4i} \Delta \mathrm{lnEAUP}_{t-i} + \sum_{i=1}^{q^4} \gamma_{5i} \Delta \mathrm{lnEN}_{t-i} + \sum_{i=1}^{q^5} \gamma_{6i} \Delta \mathrm{lnPG}_{t-i} \\ & + \sum_{i=1}^{q^6} \gamma_{7i} \Delta \mathrm{lnRPG}_{t-i} + \sum_{i=1}^{q^7} \gamma_{8i} \Delta \mathrm{lnUPG}_{t-i} + \Psi_1 \mathrm{lnGDPPC}_{t-1} + \Psi_2 \mathrm{lnEAP}_{t-1} \\ & + \Psi_3 \mathrm{lnEARP}_{t-1} + \Psi_4 \mathrm{lnEAUP}_{t-1} + \Psi_5 \mathrm{lnEN}_{t-1} + \Psi_6 \mathrm{lnPG}_{t-1} + \Psi_7 \mathrm{lnRPG}_{t-1} \\ & + \Psi_8 \mathrm{lnUPG}_{t-1} + \varepsilon_t \end{aligned} \tag{5}$$

where Δ indicates the difference operator, γ_0 represents the constant intercept, Ψ indicates the coefficients of long-run, while γ indicatesthe coefficients of short-run. The long-run co-movement among the variables of interest is ascertained on the basis of the estimated F-statistic. Pesaran et al. (2001) constituted two values available for the test of cointegration: first, the critical values of lower bound, where the variables are integrated of order zero I(0), and secondly, the critical values of the upper bound; where the variables are integrated of order one I(1). The hypothesis of no presence of long-run association is excluded if the F-statistic estimation exceeds the critical values on the upper bound. Hence, we use the small sample critical values provided by Narayan (2005) [69]. Eventually, this empirical study investigates the long-run elasticity and short-run adjustment parameters in Equation (5).

5. Results and Discussions

5.1. Unit Root Tests Results

Table 2 reports the results of the Augmented Dickey–Fuller unit root test and Phillips–Perron unit root test with intercept, and then both intercept and trend.

Table 2. Augmented Dickey–Fuller and Phillips–Perron Unit Root Test Results.

Augmented Dickey–Fuller Unit Root Test			Phillips–Perron Unit Root Test	
Variables	**At Level**	**First Difference**	**At Level**	**First Difference**
LnEAP	−1.272365	−13.17405 *	−2.945287	−16.37533 *
LnEARP	−1.664904	−11.97595 *	−2.602248	−13.37829 *
LnEAUP	−4.350711	−5.926737 *	−4.972231	−21.59359 *
LnEN	−0.673060	−4.635827 *	−0.744445	−4.634863 *
LnGDPPC	−1.575934	−4.340708 *	−1.575934	−4.318162 *
LnPG	−1.607271	−3.544057 ***	−1.703555	−3.745637 **
LnRPG	−1.232135	−4.406125 *	−1.851566	−3.908624 **
LnUPG	−2.216098	−4.502952 *	−2.422004	−4.281174 **

*, **, *** show the rejection of null hypothesis at 1%, 5% and 10% level of significance.

Augmented Dickey–Fuller unit root test results and Phillips–Perron unit root test results indicated that the significance of variables at 1%, 5%, and 10%, and none of the variables was integrated with the order of I(2); then, the ARDL model employed. Numerous cointegration approaches are available in empirical literature to test cointegration between the series, but the ARDL bounds testing is considered to be superior and preferable due to its various advantages such as: (i) no need for all of the variables in the system to be of an equal order of integration; (ii) it is an efficient estimator, even if samples are small and some of the regressors are endogenous; (iii) it allows the variables to maybe have different optimal lags; and (iv) it employs a single reduced-form equation. Thus, we opted for the ARDL approach to cointegration because of its simplicity and its suitability to models where the involved variables are of mixed order of integration [70].

5.2. Cointegration Test

A cointegration test was used when the F or W-statistic applies an upper bound of the selected significant level. It is worth observing that the F test assumes that there is no cointegration null hypothesis between variables. Cointegration results are illustrated in the Table 3.

Table 3. Autoregressive Distributed Lag (ARDL) Bounds Test for Cointegration Results.

ARDL Bounds Test for Cointegration Results				
F-Statistic	**Significance Level**	**Lower Bound**	**Upper Bound**	**Decision**
5.355108	10%	2.03	3.13	Cointegrated
	5%	2.32	3.5	
	1%	2.96	4.26	

The bounds tests shown in the table summarizes the existence of a cointegration connection among dependent and independent variables at the 1%, 5%, and 10% significance levels. Furthermore, we also employed the Johansen and Juselius, (1990) [71] cointegration test, and the results are interpreted in Table 4 with trace statistics and maximum eigenvalues.

Table 4. Results of the Johansen Cointegration test Using Trace Statistic and Maximum Eigenvalues.

Trace Statistic				
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.993717	396.7264	143.6691	0.0000
At most 1 *	0.976870	269.9806	111.7805	0.0000
At most 2 *	0.944234	175.8151	83.93712	0.0000
At most 3 *	0.816141	103.6505	60.06141	0.0000
At most 4 *	0.738330	61.31087	40.17493	0.0001
At most 5 *	0.562836	27.79407	24.27596	0.0173
At most 6	0.247014	7.107881	12.32090	0.3145
At most 7	0.000607	0.015170	4.129906	0.9198
Maximum Eigenvalue Statistic				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.993717	126.7458	48.87720	0.0000
At most 1 *	0.976870	94.16546	42.77219	0.0000
At most 2 *	0.944234	72.16461	36.63019	0.0000
At most 3 *	0.816141	42.33964	30.43961	0.0011
At most 4 *	0.738330	33.51680	24.15921	0.0020
At most 5 *	0.562836	20.68619	17.79730	0.0179
At most 6	0.247014	7.092710	11.22480	0.2415
At most 7	0.000607	0.015170	4.129906	0.9198

* Denotes rejection of the hypothesis at the 0.05 level, ** MacKinnon–Haug–Michelis (1999) *p*-values.

5.3. Long-Run Analysis Results

Long-run analysis results are interpreted in Table 5.

Table 5. Long-Run Analysis.

ARDL Cointegrating and Long-Run Form				
Cointegrating Form				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(LNEAP)	−1.828790	1.992169	−0.917989	0.3783
D(LNEARP)	1.179909	1.159803	1.017336	0.3308
D(LNEAUP)	0.184181	1.907163	0.096573	0.9248
D(LNEN)	1.549670	0.727377	2.130490	0.0565
D(LNPG)	6.825561	3.067669	2.224999	0.0479
D(LNRPG)	−6.964634	3.127366	−2.226997	0.0478
D(LNUPG)	10.114401	6.157831	1.642527	0.1287
Coint. Equation(-1)	−1.031504	0.233261	−4.422112	0.0010
Long-Run Coefficients				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LNEAP	1.310100	3.291778	0.397992	0.6983
LNEARP	−0.891821	1.868824	−0.477210	0.6426
LNEAUP	3.079896	2.910661	1.058143	0.3127
LNEN	2.288282	0.548249	4.173804	0.0016
LNPG	6.617094	2.840778	2.329324	0.0399
LNRPG	−3.988076	1.257097	−3.172450	0.0089
LNUPG	0.308340	2.151163	0.143336	0.8886
C	−27.082991	11.476944	−2.359774	0.0378

Focusing on the elasticity of the variables in the long-run analysis, the results revealed that the electricity access to the total population of Pakistan has a positive and significant impact, as the economic growth has a coefficient of 1.310100 with a p-value of 0.6983. Similarly, the coefficients of electricity access to the urban population, energy usage, population growth, and urban population growth had a positive and significant impact along with economic growth. The coefficients of the electricity access to the urban population, energy usage, population growth, and urban population growth are 3.079896, 2.288282, 6.617094, and 0.308340, with their *p*-values of 0.3127, 0.0016, 0.0399, and 0.8886, respectively. Whereas, the results of the electricity access of the rural population and rural population growth had a negative impact on the economic growth, having coefficients −0.891821 and −3.988076 with *p*-values of 0.6426 and 0.0089, respectively. The negative impact regarding the electricity access of the rural population was caused due to insufficient electricity production in the country and its supply to the rural population of the country. There is a huge gap between the supply and demand of energy, which has flared with the passage of time, and the country has limited sources for producing electricity from reliable sources, including solar, natural gas, wind energy, hydropower, and nuclear. The urban regions in the country are facing abundant load-shedding, while the rural regions face even greater load-shedding compared to their urban counterparts [72,73].

5.4. Short-Run Analysis Results

Table 6 depicted the short-run analysis results. Among the connection of variables, the cointegration presence requires an error correction model (ECM) to imprison the dynamics of the short-run relation with its coefficient, which measures the adjustment speed.

Table 6. Short-Run Analysis.

Short-Run Analysis				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
LNGDPPC(-1)	−0.031504	0.233261	−0.135061	0.8950
LNEAP	−1.828790	1.992169	−0.917989	0.3783
LNEAP(-1)	3.180164	2.076449	1.531540	0.1539
LNEARP	1.179909	1.159803	1.017336	0.3308
LNEARP(-1)	−2.099826	1.266322	−1.658209	0.1255
LNEAUP	0.184181	1.907163	0.096573	0.9248
LNEAUP(-1)	2.992745	1.832034	1.633564	0.1306
LNEN	1.549670	0.727377	2.130490	0.0565
LNEN(-1)	0.810703	0.732127	1.107325	0.2918
LNPG	6.825561	3.067669	2.224999	0.0479
LNRPG	−6.964634	3.127366	−2.226997	0.0478
LNRPG(-1)	2.850917	2.873768	0.992048	0.3425
LNUPG	10.11440	6.157831	1.642527	0.1287
LNUPG(-1)	−9.796348	6.585777	−1.487501	0.1650
C	−27.93622	11.64342	−2.399314	0.0353
R-squared	0.996705	Mean dependent var.		6.569321
Adjusted R-squared	0.992510	S.D. dependent var.		0.448658
S.E. of regression	0.038828	Akaike info criterion		−3.365683
Sum squared resid.	0.016584	Schwarz criterion		−2.639858
Log likelihood	58.75388	Hannan-Quinn criter.		−3.156672
F-statistic	237.6347	Durbin-Watson stat		2.575936
Prob(F-statistic)	0.000000			

The estimated value of R-squared is 0.996705 in the dynamics of the short-run relation, which demonstrates that about 99% variation in the economic growth was described in the model by the independent variables. The joint significance regarding the independent variables confirmed the F-statistic at a 1% level of significance. The value of the Durbin-Watson (DW) statistic was 2.575, which was not equal to the standard DW value for the nonappearance of resistance of any autocorrelation. However, this is good enough to expose whether any autocorrelation exists in the model.

Diagnostic and stability tests results are presented in Table 7.

Table 7. Diagnostic and Stability Tests.

Diagnostic and Stability Tests		
Test Statistics (LM Version)	**F-Statistic**	**Prob.**
Breusch–Godfrey Serial Correlation	2.857881	0.1346
Heteroscedasticity	0.696466	0.5095
CUSUM (Cumulative Sum)		Stable
CUSUMSQ (Cumulative Sum of Square)		Stable

Table 7 shows the Breusch–Godfrey Serial Correlation Test, and heteroskedasticity test with p-values of 0.1346 and 0.5095 respectively.

5.5. Structural Stability Test

The stability tests using the CUSUM and CUSUM square point to stabilize the long-run and short-run constraints. The graph of both CUSUM test and CUSUM square test are mentioned in Figures 9 and 10, which specify that all of the values lie within critical boundaries at a significance level of 5%. It confirms the stability of the long-run and short-run parameters.

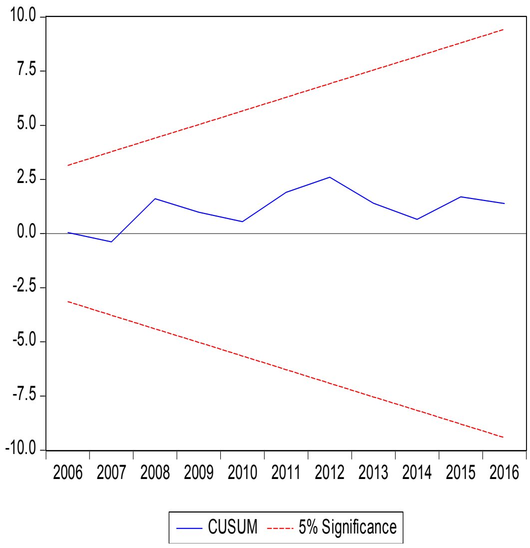

Figure 9. Plot of CUSUM.

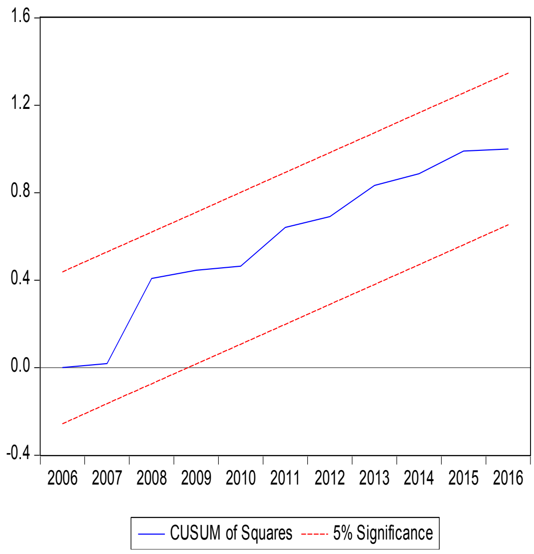

Figure 10. Plot of CUSUM of Square.

6. Conclusions and Recommendation

Pakistan has suffered from an energy crisis for the last few decades due to the insufficient production and supply of energy, causing an electricity shortage in the country. The key objective of this study was to explore and investigate the link between electricity access, energy usage, population growth, and economic growth in Pakistan. The Augmented Dickey–Fuller unit root test and Phillips–Perron unit root test were employed to gauge the stationarity of the variables, and an ARDL bounds testing approach to cointegration was applied to check the causality relationship between the study variables. The results of the study revealed that electricity access to the total population, electricity access to the urban population, energy use, population growth, and urban population growth had a significant correlation with economic growth, while the electricity access to the rural population and rural population growth present a negative correlation with economic growth. The population of Pakistan is growing with the passage of time; more electricity is required to fulfill the country's demands. For the production of electricity, new policies require implementation in order to boost the energy sector of the country. The government should also pay attention to producing energy from alternative sources. These alternative sources include natural gas, coal, solar power, and wind. Natural gas and oil are the dominant sources that are used to produce energy in the country. Possible initiatives need to be undertaken to produce energy using solar power in order to supply cheap electricity to the population of the country. Regarding production from hydropower, necessary steps should be taken to build new dams in the country for storing water, which is also crucial for agricultural growth to boost the country's economic growth. This will also present other benefits, as Pakistan will also face a water crisis in the coming years, which will be a serious threat to the country. The government should also formulate short-term, medium-term, and long-term energy production plans in order to produce cheap energy for fulfilling the country's demand for electricity.

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