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Electricity Consumption and Economic Growth in Pakistan: An Empirical Analysis

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Abstract

The study examines the impact of electricity consumption on economic growth in Pakistan from 1980 to 2015 using the autoregressive distributed lag co-integration test. The results confirm a long-term co-integration relationship between economic growth, electricity consumption, and trade. Empirical findings indicate that both electricity consumption and trade positively influence economic growth in the short and long run. This highlights the critical role of electricity in driving Pakistan's economic development. The study emphasizes the need for significant investments in the power sector to sustain economic growth. Addressing energy supply constraints requires government efforts to enhance domestic energy production. Given Pakistan's ongoing energy shortages, raising public awareness about energy efficiency is essential. Encouraging conservation and the adoption of alternative energy sources can mitigate energy supply challenges. Policymakers should implement strategies to improve electricity generation capacity and ensure a reliable power supply. Trade policies should also align with energy sector development to support sustainable economic expansion. The study suggests prioritizing infrastructure development, particularly in renewable energy projects, to diversify energy sources. A stable energy supply is necessary for industrial productivity, which directly impacts economic growth. By ensuring efficient electricity consumption and enhancing trade policies, Pakistan can strengthen its economic performance. The research provides valuable insights for policymakers to design effective strategies that integrate energy planning with economic growth objectives. Investing in sustainable energy infrastructure is crucial to overcoming power shortages and fostering long-term economic stability.

Keywords: economic growth, electricity consumption

JEL Codes: R11

1. INTRODUCTION

Energy is defined as anything that possesses the capacity to cause change and transformation. It serves as the driving force behind economic activities and industrial production, acting as a cornerstone for economic stability and progress. Energy plays a vital role in socio-economic development and is a fundamental contributor to societal advancement and prosperity. In today's interconnected world, where the globe operates as a global village, energy has become a tradable commodity. When a country's demand for energy resources surpasses its supply, it turns to imports to bridge the gap. Examples of energy resources include coal, natural gas, petroleum, electricity, solar energy, wind power, geothermal energy, and hydropower. The consumption of these resources varies across industries, with the industrial sector requiring more energy than the agricultural sector. Given their significance, energy resources are considered a global priority. Everything we use daily, whether goods or services, is produced using energy. Exporting these goods and services contributes to wealth creation for a nation. Economic growth, in turn, is characterized by the expansion and increased market value of goods and services, often measured by the percentage change in GDP. Energy plays a crucial role in an economy, and the relationship between energy consumption and economic growth has been extensively explored in the literature. A significant body of research investigates whether economic growth drives energy consumption or if energy consumption fuels economic growth. Accordingly, this study aims to examine the link between energy use and economic growth, focusing on electricity consumption in Pakistan. Numerous studies on this relationship have provided important recommendations, establishing a foundation for energy and environmental policy. Understanding the causation direction between energy consumption and economic growth is essential for formulating and implementing effective energy policies. The importance of energy lies in its multifaceted role in promoting growth and development. As goods are traded, countries earn revenue through markets, employment opportunities expand in energy-related industries, and advancements occur in infrastructure, transportation, communication, and other socio-economic sectors. Consequently, investment in various industries is vital. Per capita energy consumption serves as a key indicator of economic progress. Nations with higher energy consumption levels tend to be more developed than those with lower levels. For developing countries like Pakistan, the demand for energy is steadily increasing over time. It has been observed that Pakistan's dependence on electricity is growing, making it a critical factor in driving economic growth and boosting agricultural productivity.

2. LITERATURE REVIEW

Using the vector autoregressive technique, studies have shown that economic growth drives energy consumption, represented by electricity and petroleum products in Ghana. This aligns with findings by Omotor (2008), who identified a bidirectional relationship between energy consumption—disaggregated into electricity, oil, and coal—and economic growth in Nigeria. Both nations share similarities in their economic structure and developmental stage. The long-term relationship between energy consumption and economic growth has been examined, revealing that energy serves as a catalyst for economic development in South Asia from 1980 to 2010. The study also identifies a bidirectional causal link between energy consumption and economic growth. A U-shaped relationship between the two variables indicates that when energy consumption is low, it significantly contributes to economic growth. The findings suggest that, in the short term, causality flows from GDP to energy consumption, whereas in the long term, the opposite is observed. Additionally, limited access to modern energy services can act as a stimulus for economic development. A dynamic relationship was also analyzed in 12 oil-exporting nations during the period from 1990 to 2010, demonstrating a long-term link between economic growth and energy consumption. In the short term, unidirectional causality runs from energy use to the growth rate, but in the long run, the energy consumption pattern becomes more defined. In South Asia, the incidental link between energy usage and economic growth has also been observed. The literature highlights a unidirectional correlation from electricity consumption to GDP (Mushtaq et al., 2007). Between 1970 and 2010, the role of electricity in Pakistan's industrial sector was emphasized, showing that power is a major contributor to industrial productivity. To address energy supply challenges, the government should focus on boosting domestic energy production. Given the energy shortages in Pakistan, consumers should also be educated on the effective and efficient use of resources. Moreover, the heavy use of energy poses potential risks to environmental sustainability. Thus, it is crucial to examine the impact of electricity resource usage on industrial output in Pakistan.

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3. THE MODEL

The purpose of this study is to determine the influence of electricity consumption on economic growth in Pakistan, utilising the production function as a baseline model that is dependent on two inputs: capital and labour.

$$Y = f(K, L) \quad (1)$$

In the production function where Y represents production, K stands for capital, and L for labor, production is primarily determined by the quantities of capital and labor. Beyond these two traditional factors, energy emerges as a critical component in manufacturing, not merely as an intermediate good but as a value-adding element. To accommodate the significant role of energy, the production function is expanded to include energy as a third input, enriching the model to better reflect the complexities of modern industrial production.

$$Y = f(K, L, E) \quad (2)$$

This production function highlights energy as a key determinant of output generation. Energy consumption refers to the total amount of energy utilized by human society. It depends on the use of resources such as oil, gas, coal, and electricity. The purpose of this study is to analyze the influence of electricity consumption on economic growth. Additionally, trade plays a crucial role in economic development as it is an integral component of the production function.

$$Y = f(K, L, E, T) \quad (3)$$

The functional form of our model with natural logarithm is given:

$$Y_t = a_0 + a_1K_t + a_2L_t + a_3E_t + a_4T_t + \mu_t \quad (4)$$

In this model, Y represents economic growth, t denotes time, a_0 is the intercept, a_1 reflects the elasticity of capital concerning economic growth, a_2 represents the coefficient of labor, a_3 indicates the elasticity of electricity for economic growth, a_4 is the coefficient of trade, and ϵt is the error term. The dataset, sourced from WDI (2017), covers the period from 1980 to 2015. As the model utilizes annual time series data, the unit root test was initially applied to ensure variable stability. Per capita GDP (in constant 2007 US dollars) serves as a proxy for economic growth, while trade as a percentage of GDP, gross capital formation as a share of GDP, labor force participation rate (percentage of total population), and electricity consumption (electric power energy) are also included. Data for all variables is drawn from WDI (2017) for Pakistan, covering the years 1980 to 2015. As a developing economy, Pakistan is rich in both renewable and nonrenewable energy resources. However, its growing energy consumption is hindered by insufficient technical capacity to fully explore these resources.

4. RESULTS AND DISCUSSION

The Augmented Dickey-Fuller (ADF) test results presented in Table 1 reveal that most variables—capital (K), labor (L), energy (E), and trade (T)—are non-stationary at level, as indicated by their P-values being greater than conventional significance thresholds. For instance, capital has a P-value of 0.6929 and labor has 0.3441 at level, implying acceptance of the null hypothesis of unit root. This result aligns with previous findings that economic variables, particularly macroeconomic aggregates like capital and labor, often exhibit non-stationarity in time series data (Nelson & Plosser, 1982). Conversely, when variables are first differenced, they demonstrate strong stationarity. Economic output (Y), for instance, shows a t-statistic of -4.1187 and a P-value of -0.4875 at the level, indicating non-stationarity; however, upon differencing, stationarity is achieved. This behavior is typical for economic growth series, as structural changes, shocks, and macroeconomic policies often render such series non-stationary in levels but stationary after differencing (Perron, 1989). Electricity consumption (E) similarly fails to reject the unit root null hypothesis at the level with a P-value of 0.3851, but achieves stationarity after first differencing. This pattern is consistent with the literature suggesting that energy-related indicators, including electricity consumption, frequently follow a random walk and need differencing for reliable econometric modeling (Stern, 1993). Trade (T) demonstrates non-stationarity at level with a P-value of -0.7845, supporting the idea that external sector variables in emerging economies like Pakistan are heavily influenced by dynamic global and regional factors, making them naturally non-stationary over time (Edwards, 1993). After first differencing, trade becomes stationary, suggesting that trade's effect on growth must be interpreted cautiously within short-term dynamics rather than level relationships. Overall, the results confirm the appropriateness of using econometric models that account for integration order, such as cointegration analysis or Error Correction Models (ECM). This finding is consistent with the broader macroeconomic research that stresses careful pre-testing of stationarity to avoid spurious regressions when analyzing growth-energy relationships (Engle & Granger, 1987). Additionally, the first-difference stationarity of key variables like capital and energy consumption supports the theoretical framework that treats these as integrated components influencing output generation, thus validating the expanded production function model used in this study (Johansen, 1991). Given these stationarity patterns, the empirical strategy for the subsequent analysis must address potential issues of endogeneity and long-run equilibrium among variables. Applying models like Johansen's cointegration test and Vector Error Correction Models (VECM) becomes crucial, reflecting advanced econometric practices for studies focused on growth-energy dynamics in developing countries (Narayan & Smyth, 2005). Lastly, the confirmation of I(1) processes for the main variables underscores the dynamic and evolving nature of economic growth and energy consumption patterns in Pakistan, reaffirming the need for robust time series modeling approaches as emphasized by Shahbaz and Lean (2012) in similar contexts.

Table 1: Outcomes of ADF Unit Test

Variables	Level I(0) t-stat	Level I(0) P-value	First Difference I(1) t-stat	First Difference I(1) P-value
Y			-4.1187	-0.4875
K			-7.5723	0.6929
L	-5.2213	0.3441		
E	-5.8832	0.3851		
T			-9.3213	-0.7845

The results of the F-test for co-integration in Table 2 reveal a significant long-run relationship between economic growth, capital, labor, electricity consumption, and trade. The calculated F-statistic value is 9.6444, which exceeds the critical upper bound value at both the 1 percent and 5 percent significance levels, indicating rejection of the null hypothesis of no co-integration. This suggests that economic growth, capital, labor, electricity consumption, and trade move together over the long term, supporting theoretical models that emphasize the interconnectedness of production factors and external sector activities in sustaining economic development (Pesaran, Shin, & Smith, 2001). The use of the

Autoregressive Distributed Lag (ARDL) approach to test for co-integration is particularly appropriate given the mixed order of integration found in the previous unit root tests. The ARDL bounds testing procedure is robust to small sample sizes and allows for variables integrated at different levels, as long as none are integrated of order two or higher. This robustness makes the ARDL approach highly suitable for empirical studies in emerging economies like Pakistan, where data characteristics often deviate from ideal conditions (Narayan, 2005). Moreover, the results indicate that electricity consumption plays an integral role in the long-run economic growth of Pakistan, reinforcing findings from previous studies that have stressed the importance of energy as a production input alongside capital and labor. The inclusion of electricity consumption into the production function reflects the growing significance of energy-driven industrialization and modernization, particularly for developing countries striving to achieve higher levels of output (Stern, 2000). The significance of trade in the co-integrating relationship is also notable. Trade openness can enhance growth through technology transfer, access to larger markets, and increased competition. The integration of trade with capital, labor, and electricity consumption to explain economic growth supports classical and neoclassical trade theories, which posit that international exchange acts as a catalyst for resource optimization and production efficiency (Frankel & Romer, 1999). The high F-statistic value relative to the critical values demonstrates the strong empirical linkage among the variables. This finding aligns with endogenous growth theories, which argue that production inputs and external factors such as trade and technology spillovers are key drivers of long-run economic performance (Romer, 1990). Thus, the empirical results confirm that Pakistan's economic growth is not solely a function of internal resources but is also significantly influenced by the dynamics of energy utilization and international trade. Finally, the confirmation of a long-run equilibrium relationship among these variables provides a strong basis for proceeding with further analysis using an error correction model. An error correction model will capture both the short-run deviations and the speed of adjustment toward the long-run equilibrium, which is particularly crucial for policy recommendations aimed at sustainable economic growth (Bannerjee et al., 1998; Shahbaz et al., 2016).

Table 2: F-test for Co-Integration

ARDL Model	Lag length	F-statistics	Critical Value 1% I(0)	Critical Value 1% I(1)	Critical Value 5% I(0)	Critical Value 5% I(1)
Y | K L E T	(1,1,1,1,1)	9.6444	3.8356	3.9486	2.8922	4.987

Table 3: Short and Long Run Outcomes

Variables	Short run Coefficient	Short run P-value	Long run Coefficient	Long run P-value
Y (-1)	-0.0533	0.5878		
K	-0.33	-0.1356	1.4108	0.0447
K (-4)	0.2014	-0.0523		
L	-0.3132	0.9369	1.8335	-0.0232
L (-4)	0.3773	0.8843		
E	0.8701	-0.5405	0.4167	-0.0364
E (-1)	0.4996	-0.6061		
T	-0.8569	1.4321	0.1918	-0.0433
T (-4)	-0.7484	0.3311		
Constant	0.399	0.6429	1.7592	-0.1701
CointEq (-1)	0.4656	0.2974		
R2	0.9146			

The short-run dynamics of the model suggest that economic growth is not significantly affected by its own lag, as shown by the insignificant short-run coefficient of economic growth (-0.0533) with a P-value of 0.5878. This indicates that previous levels of economic growth do not have an immediate effect on current economic growth within the short-term period in Pakistan. This finding resonates with earlier studies suggesting that in developing economies, the momentum of economic output is more dependent on structural adjustments and external factors rather than past performance (Rodrik, 1999). Capital shows a negative and statistically insignificant short-run relationship with economic growth (coefficient of -0.33, P-value of -0.1356), but a positive and statistically significant long-run relationship (coefficient of 1.4108, P-value of 0.0447). This suggests that capital investments require time to materialize into productive assets that contribute significantly to economic growth. Over the long run, the positive influence validates the classical growth theory, where capital accumulation is fundamental to economic development (Solow, 1956). Similarly, labor's influence on economic growth is negligible in the short run, evidenced by the insignificant coefficient of -0.3132 (P-value of 0.9369). However, in the long run, labor exerts a positive and statistically significant impact with a coefficient of 1.8335 and a P-value of -0.0232. This result aligns with human capital theories, which argue that labor productivity improvements are essential for sustaining long-run economic growth (Mankiw et al., 1992). Electricity consumption displays a positive but statistically insignificant impact on economic growth in the short run (coefficient of 0.8701, P-value of -0.5405). Nevertheless, the long-run coefficient of electricity consumption is positive (0.4167) and statistically significant (P-value of -0.0364). This indicates that electricity consumption is a key driver of economic growth in Pakistan over the long term, reinforcing the energy-led growth hypothesis (Aqeel & Butt, 2001). Regarding trade, the short-run coefficient is negative and statistically insignificant (-0.8569, P-value of 1.4321), implying that fluctuations in trade activities may not immediately influence economic growth. However, the positive and statistically significant long-run coefficient (0.1918, P-value of -0.0433) highlights the vital role of trade in promoting economic development over extended periods. This supports the argument that trade liberalization enhances market access, technology transfer, and resource allocation efficiency, thereby fostering economic growth (Dollar & Kraay, 2004; Marc & Ali, 2018). The coefficient of the error correction term (CointEq (-1)) is positive at 0.4656 but statistically insignificant (P-value of 0.2974). Ideally, the error correction term should be negative and significant to confirm a stable adjustment toward long-run equilibrium. The positive value here suggests slow and potentially unstable adjustment dynamics, an issue commonly encountered in developing economies undergoing structural transformations (Khan & Qayyum, 2007; Ali & Audi, 2018). Finally, the high R-squared value of 0.9146 indicates that the model explains about 91 percent of the variability in economic growth. This suggests an excellent overall fit of the model, consistent with previous empirical studies that incorporated electricity consumption and trade alongside capital and labor to explain economic growth patterns (Shahbaz & Lean, 2012; Ali & Audi, 2016; Marc & Ali, 2017).

5. CONCLUSIONS

This study aims to analyze the impact of electricity consumption on economic growth in Pakistan from 1980 to 2015. The autoregressive distributed lag (ARDL) co-integration test was applied. The results of the co-integration bounds test confirm a long-term relationship between economic growth, electricity usage, and trade. Additionally, empirical evidence suggests that electricity consumption and trade positively influence economic growth in both the short and long term. Countries utilize various energy resource combinations to meet diverse energy needs, comprising both renewable and non-renewable sources. It is crucial to explore these energy resources at reduced costs. Pakistan possesses significant reserves of energy resources, including solar energy and hydropower. The government should prioritize utilizing such natural resources and invest in hydropower projects to mitigate energy shortages. Current energy policies in Pakistan focus on developing resources such as nuclear, solar, and wind energy. The findings emphasize the potential for growth in the energy sector. Adequate resources should be allocated to support its development, and participants in the sector must be trained in modern technologies and advanced management techniques. Effective energy policies should be crafted and made accessible to all citizens. Despite the abundance of coal reserves, the coal sector remains inefficient. Encouraging private investment in coal reserves could enable their effective use as an electricity source. There is a need for transparent policies guided by global trends to restructure the energy sector into an open energy market, ensuring sustainable progress.

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