Vol. 3(4), 104-111

Journal of Energy & Environmental Policy Options

The Role of Energy in Facilitating Economic Development in Pakistan

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Abstract
The implementation of World Trade Organization policies facilitates international trade by removing restrictions, thereby enabling countries to engage in global markets more freely. This liberalization of trade offers significant opportunities for both developed and developing nations to expand their economic activities. By participating more actively in international trade, these countries can capture a larger share of both domestic and international markets. The expansion of economic activities resulting from open trade policies naturally creates an increased demand for energy. As countries strive to produce more goods to meet the growing demands of both local and global markets, their energy consumption rises. This trend is particularly evident in developing countries like Pakistan, where economic growth is closely tied to energy availability. The present study investigates the relationship between energy consumption and economic growth in Pakistan. The findings indicate a positive long-term relationship between these two variables. In other words, as energy consumption increases, so does economic growth. This relationship underscores the critical role that energy plays in fueling economic development. Without adequate energy supplies, it is challenging for any country to sustain its growth trajectory. However, the study also highlights a significant concern: the acute shortage of energy in Pakistan. The country faces persistent energy crises, characterized by frequent power outages and an overall inadequate supply of electricity and other forms of energy. This shortage not only hampers industrial productivity but also affects everyday life, reducing the quality of living and hindering economic progress. Higher energy prices compound this problem. When energy prices rise, the cost of production increases, leading to higher prices for goods and services. This situation can lead to inflationary pressures, reducing the purchasing power of consumers and slowing down economic growth. Businesses may find it difficult to operate profitably under such conditions, which can result in reduced investments and job losses, further exacerbating the economic challenges. The study's findings suggest that for Pakistan to achieve sustainable economic growth, it must address its energy issues. Ensuring a stable and affordable energy supply is crucial. This could involve investing in energy infrastructure, exploring alternative and renewable energy sources, and implementing policies that encourage energy efficiency. By taking these steps, Pakistan can not only meet its current energy demands but also prepare for future needs, supporting long-term economic growth. Moreover, the study emphasizes the importance of aligning energy policies with broader economic strategies. A holistic approach that considers the interplay between energy availability and economic activities can help create a more resilient economy. This involves not just increasing energy production but also improving energy distribution and consumption practices.
Keywords: Energy Consumption, Economic Growth, Trade Liberalization
JEL Codes: F13, O13, Q43

1. INTRODUCTION

Today, trade has expanded beyond domestic markets into international markets, creating intense competition among industries globally. Each country aims to boost economic activities and achieve high GDP growth rates. Efficient utilization of production factors such as labor and capital is crucial for increasing production. In addition to these factors, energy plays a pivotal role in determining production levels, as industries heavily rely on electricity. Acute shortages and high costs of electricity can significantly hinder growth, impacting the overall economic development. Thus, ensuring a stable and affordable energy supply is essential for sustaining industrial competitiveness and economic progress. The importance of energy, particularly electricity, in industrial production cannot be overstated. Industries, ranging from manufacturing to high-tech sectors, require a reliable and continuous energy supply to maintain operations, meet production targets, and avoid costly downtimes. Any disruption in electricity supply can lead to substantial losses in productivity and revenue. Furthermore, the cost of electricity directly affects the competitiveness of industries. High electricity costs can erode profit margins, making it difficult for domestic industries to compete with international counterparts who might have access to cheaper energy sources. In developing countries, the challenges associated with electricity supply are often more pronounced. Inadequate infrastructure, lack of investment, and inefficient energy policies can lead to frequent power outages and unreliable electricity

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supplies. This not only hampers industrial growth but also affects other sectors such as healthcare, education, and services, thereby impeding overall economic development.

Moreover, the shift towards sustainable energy sources presents both challenges and opportunities. While transitioning to renewable energy sources like solar, wind, and hydroelectric power is essential for long-term sustainability and environmental protection, the initial investment and technological adaptation can be significant. Industries need to innovate and adapt to new technologies to ensure that the transition is smooth and does not disrupt production processes. In addition, government policies and regulations play a crucial role in shaping the energy landscape. Supportive policies, subsidies for renewable energy projects, and investments in infrastructure can create a conducive environment for industries to thrive. Conversely, inconsistent policies and lack of support can deter investment and slow down progress. The interplay between energy supply and economic growth is complex and multifaceted. Ensuring a stable, affordable, and sustainable energy supply is key to fostering industrial growth, enhancing competitiveness, and achieving broader economic development goals. For countries looking to improve their economic standing, addressing the challenges in the energy sector is a critical step towards sustainable growth and development. Empirical evidence indicates that acute electricity shortages have significantly deteriorated economic activities and stunted economic growth. Stern and Cleveland (2004) employed biophysical theory and mainstream resource economics models of growth, concluding that energy is a crucial input for accelerating growth. Pakistan has faced a severe electricity shortage in recent years, compounded by rising energy prices, which has led to a decline in the industrial sector's contribution to GDP. In 2008, the country experienced a negative growth rate in electricity generation, which further reduced the GDP growth rate.

The electricity crisis in Pakistan has created a ripple effect across various sectors of the economy. Industries, in particular, have borne the brunt of power shortages, leading to reduced production capacity, increased operational costs, and diminished competitiveness both domestically and internationally. This energy shortfall has also deterred potential foreign and domestic investments, as investors seek more stable and reliable energy environments for their ventures. In addition to the industrial sector, the agricultural and service sectors have also been adversely affected. Agricultural production, which relies on energy for irrigation and processing, has faced disruptions, thereby impacting food security and export potential. Similarly, the service sector, which includes critical areas such as healthcare, education, and finance, has struggled with unreliable electricity, hampering service delivery and economic productivity. The rising cost of energy has further exacerbated the situation. Increased energy prices have led to higher production costs, which are often passed on to consumers, resulting in inflationary pressures. This scenario not only affects the cost of living but also reduces disposable income, thereby limiting consumer spending and overall economic activity. To address these challenges, comprehensive and sustainable energy policies are essential. Investment in renewable energy sources such as solar, wind, and hydroelectric power can provide long-term solutions to the energy crisis. Additionally, upgrading and expanding the existing energy infrastructure can improve efficiency and reduce transmission losses. Government initiatives to incentivize energy conservation and promote efficient energy use can also play a significant role in mitigating the impact of energy shortages.

Moreover, regional cooperation and cross-border energy trade can help stabilize the energy supply. By leveraging the energy resources of neighboring countries, Pakistan can enhance its energy security and reduce the dependency on expensive and volatile energy imports. The acute shortage of electricity in Pakistan has had a profound impact on economic growth, particularly in the industrial sector. Addressing this issue through sustainable energy policies, infrastructure investments, and regional cooperation is crucial for revitalizing economic activities and achieving long-term economic stability and growth. Energy is a fundamental input for the economic development of any country, acting as a cornerstone for industrial growth, technological advancement, and overall societal well-being. The energy sector is inherently multidisciplinary, encompassing aspects of engineering, economics, environmental science, and policy. Developing energy infrastructure demands significant investment and involves substantial costs, with many projects requiring long lead times for planning, approval, and construction. Consequently, decisions made regarding energy infrastructure at any given time have considerable and long-term financial implications.

Considering the critical role of energy in driving economic progress, it is imperative for a country to generate sufficient energy to meet the demands of all sectors. This includes industrial, residential, commercial, and agricultural sectors, each of which relies heavily on a stable and adequate energy supply. A mismatch between energy supply and demand can lead to power shortages, increased costs, and economic instability, hampering growth and development. To achieve a balance between energy supply and demand, diversification of energy sources is essential. Relying on a mix of energy sources, including fossil fuels, nuclear power, and renewables such as solar, wind, and hydroelectric power, can enhance energy security and reduce vulnerability to supply disruptions. Diversification also helps mitigate the environmental impacts associated with energy production. Investing in renewable energy is particularly crucial as these sources are sustainable and environmentally friendly. Government incentives and subsidies can encourage the adoption of renewable energy technologies, providing long-term solutions to energy shortages while reducing carbon emissions.

Energy efficiency and conservation are critical strategies for reducing overall energy consumption and lowering costs. Implementing energy efficiency measures across all sectors, such as upgrading infrastructure, promoting energy-efficient appliances, and encouraging practices that minimize energy waste, can significantly contribute to a more sustainable energy system. Additionally, upgrading existing energy infrastructure and developing new projects are crucial for meeting future energy demands. Building new power plants, expanding transmission networks, and modernizing grid systems improve

reliability and efficiency, ensuring a stable energy supply. Regional cooperation and energy trade can also enhance energy security and stability. Collaborating with neighboring countries through regional energy agreements allows for cross-border energy trade, leveraging each other's resources to ensure a more stable and diversified energy supply. Establishing robust policies and regulatory frameworks is essential for guiding the development and management of the energy sector. Setting standards for energy production, distribution, and consumption, as well as providing a conducive environment for investment, can drive progress in the energy sector.

Raising public awareness about the importance of energy conservation and the benefits of renewable energy is vital for fostering a culture of sustainability. Educational programs can inform citizens about energy-saving practices and the environmental impact of their energy choices. By focusing on these strategies, a country can create a resilient and sustainable energy system that supports economic growth and development. Ensuring that energy supply matches the demand of all sectors is vital for maintaining economic stability, improving quality of life, and achieving long-term development goals. Several factors contribute to the persistent energy crises and the widening gap between energy demand and supply. Among these factors, transmission and distribution (T&D) losses are particularly significant. These losses occur during the process of delivering electricity from power plants to consumers, and they represent a substantial inefficiency in the energy system. T&D losses are estimated to account for approximately 24-29% of the electricity generated, meaning nearly a quarter of all produced electricity is lost before it reaches end-users. These losses can occur due to various reasons, including technical issues like outdated infrastructure, poor maintenance, and inefficiencies in the transmission lines. Additionally, non-technical losses, such as electricity theft and billing inefficiencies, also contribute to the overall T&D losses.

The financial impact of these losses is profound. The cost of the lost electricity is typically recovered from paying consumers, effectively increasing the overall cost of electricity for those who comply with billing. This not only places a financial burden on consumers but also undermines the economic efficiency of the energy sector. High T&D losses reduce the revenue available to energy providers, limiting their ability to invest in infrastructure improvements and new energy projects. Reducing T&D losses is crucial for addressing energy crises and improving the efficiency of the energy system. Modernizing and upgrading the existing infrastructure can significantly reduce technical losses. This includes replacing old and inefficient transmission lines, installing advanced metering systems, and implementing better maintenance practices. Investing in smart grid technologies can also enhance the monitoring and management of electricity flows, helping to identify and rectify inefficiencies more quickly. Addressing non-technical losses requires a combination of policy measures, enforcement, and community engagement. Strengthening regulations and penalties for electricity theft, improving billing accuracy, and increasing transparency in the energy sector can help reduce non-technical losses. Public awareness campaigns and community involvement are also essential to fostering a culture of compliance and reducing electricity theft. In addition to infrastructure improvements and regulatory measures, diversifying energy sources can help alleviate the pressure on the energy system. Integrating renewable energy sources, such as solar and wind power, can reduce the strain on traditional power plants and provide a more sustainable and reliable energy supply. Renewable energy projects often have lower T&D losses, as they can be decentralized and closer to the point of use, reducing the distance electricity needs to travel. Efforts to reduce T&D losses must be complemented by broader energy efficiency initiatives. Encouraging consumers to adopt energy-efficient appliances and practices can lower overall energy demand, easing the pressure on the energy system. Implementing energy-saving measures in industrial, commercial, and residential sectors can contribute to a more balanced and sustainable energy supply.

2. LITERATURE REVIEW

The relationship between electricity consumption and GDP growth has been extensively studied by researchers, yielding significant insights into their interdependence. Empirical results consistently suggest a causality between electricity consumption and economic growth, underscoring the critical role of energy in driving economic activities. Bekhet and Othman (2011) conducted a comprehensive study examining this relationship in Malaysia over the period from 1971 to 2009. They utilized a vector error correction model (VECM) to analyze the long-term relationships among electricity demand, real per capita income, prices, and foreign direct investment (FDI). Their findings indicated a strong long-run relationship among these variables, highlighting the interconnectedness of electricity consumption with key economic indicators. Furthermore, the Granger Causality test applied in their study revealed the existence of long-run causality among electricity consumption, FDI, real per capita income, and inflation. This implies that changes in electricity consumption can predict future changes in these economic variables, and vice versa, emphasizing the mutual influence between energy consumption and economic performance. The study concluded that electricity consumption is a crucial determinant of economic growth in Malaysia. It stressed the importance of ensuring a stable electricity supply to achieve sustainable economic development. The findings suggest that policymakers should prioritize the stability and reliability of electricity supply to support economic activities and foster long-term growth.

The implications of Bekhet and Othman's research extend beyond Malaysia, providing valuable insights for other developing countries facing similar challenges. Stable and reliable electricity supply is essential for attracting FDI, enhancing productivity, and improving the standard of living. It is a key enabler of industrialization, technological advancements, and overall economic progress. Udah (2010) explored the intricate relationship between electricity supply and economic growth in Nigeria, revealing significant insights through the application of the Auto Regressive Distributed Lag (ARDL) model and

Granger causality test. The study spanned the period from 1970 to 2008, providing a comprehensive analysis of the long-term dynamics between key economic variables. Udah's findings indicate a causal relationship between electricity supply and per capita income, underscoring the critical role of energy availability in driving economic well-being. The study demonstrated that an increase in electricity supply directly influences per capita income, suggesting that improvements in energy infrastructure can enhance the standard of living and economic prosperity. Furthermore, Udah identified a unidirectional causality among electricity supply, capital employed, and labor. This means that changes in electricity supply have a direct impact on the amount of capital employed and the labor force, but not vice versa. The availability of reliable electricity facilitates industrial activities, boosts productivity, and encourages the employment of capital and labor, which are essential for economic growth. The conclusion drawn from Udah's research is that electricity supply serves as one of the primary driving forces for economic growth through industrialization. By ensuring a steady and reliable supply of electricity, Nigeria can stimulate industrial activities, which in turn catalyze economic expansion and development. This finding is particularly relevant for policymakers aiming to achieve sustainable growth, as it highlights the importance of investing in and maintaining robust energy infrastructure. Udah's study contributes to a broader understanding of the critical link between energy supply and economic growth, aligning with findings from other research that emphasize the importance of stable energy provision in fostering development. In the context of Nigeria, ensuring reliable electricity supply is paramount for leveraging industrialization as a means to drive economic growth, enhance productivity, and improve living standards.

Bayrakyutan et al. (2011) conducted a comprehensive study to explore the long-run relationship and causality between electricity generation and economic growth. By employing an energy demand function, the researchers analyzed panel data from 40 OECD countries over the period of 1980-2007. Their findings provide significant insights into the dynamic interplay between energy production and economic development. The study concluded that there is a long-run positive relationship between electricity generation and economic growth. This indicates that as countries increase their electricity production, their economic output tends to rise correspondingly. The positive correlation underscores the importance of expanding energy generation capacities to foster economic development. An important aspect of Bayrakyutan et al.'s research is the focus on renewable energy sources. The findings suggest that increasing electricity generation from renewable resources, such as wind, solar, and hydroelectric power, has a significant positive impact on economic growth. This highlights the dual benefits of investing in renewable energy: not only do these sources contribute to a sustainable and cleaner environment, but they also drive economic progress. Moreover, the study identified a bidirectional causality between electricity generation and economic growth. This means that not only does electricity generation influence economic growth, but economic growth also stimulates further electricity production. This reciprocal relationship emphasizes the intertwined nature of energy and economic policies. As economies grow, the demand for energy increases, necessitating further investment in energy infrastructure. Conversely, advancements in energy generation technology and capacity can catalyze economic expansion by powering industries, enhancing productivity, and supporting innovation. Bayrakyutan et al.'s research aligns with other empirical studies that emphasize the critical role of energy in economic development. The bidirectional causality underscores the need for a balanced approach in policy formulation, where energy infrastructure investments and economic growth strategies are harmonized to achieve sustainable development.

Clement and Ighodaro (2010) conducted a significant study focusing on the relationship between energy consumption and economic growth in Nigeria. Their research utilized various proxies for energy, including electricity demand, domestic crude oil consumption, and gas utilization, to analyze time series data spanning from 1970 to 2005. The study's findings indicate a robust long-run relationship between energy consumption and economic growth in Nigeria. This suggests that as energy consumption increases over time, it positively influences the country's economic output and development. The relationship underscores the pivotal role of energy as a fundamental input in driving economic activities across sectors. Furthermore, Clement and Ighodaro's research identified a causal relationship between energy consumption and economic growth. This causal link implies that changes in energy consumption levels lead to corresponding changes in economic growth rates. Specifically, increases in energy consumption are associated with enhanced economic performance, while declines in energy consumption can potentially dampen economic growth. The study's conclusions are particularly relevant for policymakers and stakeholders in Nigeria's energy and economic sectors. By recognizing the significant impact of energy consumption on economic growth, policymakers can prioritize strategies that enhance energy efficiency, expand energy infrastructure, and promote sustainable energy sources. These initiatives are crucial for ensuring stable and resilient economic development, as well as for mitigating the potential adverse effects of energy shortages or inefficiencies on the economy.

Chen et al. (2007) conducted a study examining the relationship between electricity consumption and economic growth across 10 newly industrialized and developing Asian countries using panel data spanning from 1971 to 2001. Their research identified a long-run relationship between electricity consumption and economic growth, indicating that as electricity consumption increased over time, it positively influenced economic performance in these countries. Moreover, Chen et al. found that the causal relationship between electricity consumption and economic growth exhibited unidirectional characteristics. This suggests that changes in electricity consumption levels preceded changes in economic growth rates, indicating that electricity consumption acted as a driving force for economic development in the studied countries. These findings underscore the critical role of electricity as a fundamental input in promoting economic growth and development in emerging economies. By enhancing electricity infrastructure, improving energy efficiency, and promoting sustainable energy practices, policymakers can effectively support economic expansion and enhance overall societal well-being. Chen et al.'s

study contributes valuable insights into the dynamics of the electricity-economy nexus in the context of Asian developing countries, providing empirical evidence to inform energy policy and investment decisions aimed at fostering sustainable and inclusive economic development.

Acaravci (2010) concluded that there is a long-run relationship between energy consumption and economic growth in Turkey. This finding was supported by several studies, including Kiran and Guris (2009), Altinay and Karagol (2005) for Turkey, and Morimoto and Hope (2001) for Sri Lanka. These studies collectively suggest that energy consumption plays a significant role in driving economic growth over extended periods. The causal relationship between energy consumption and economic growth was empirically established for Turkey, spanning from 1968 to 2005. This timeframe allowed researchers to analyze how changes in energy consumption patterns influenced economic performance over decades. The findings underscored the importance of energy as a critical input in Turkey's economic development, influencing productivity, industrial output, and overall economic resilience. These insights contribute to the broader understanding of energy's impact on economic growth across different contexts, providing valuable implications for energy policy and sustainable development strategies. By ensuring efficient energy use, promoting renewable energy sources, and enhancing energy infrastructure, countries like Turkey can sustainably support their economic growth trajectory while addressing environmental and social challenges.

Masih and Masih (2007) and Chandran (2010) concluded that there is unidirectional causality running from electricity consumption to GDP in Indonesia. This suggests that changes in electricity consumption influence GDP, reflecting the importance of energy supply in supporting economic activities in Indonesia. However, Lean et al. (2010) found different results. They empirically estimated bidirectional causality between aggregate output and electricity consumption, indicating that changes in both electricity consumption and GDP can affect each other in a mutually reinforcing manner. In Taiwan, Lang (2010) similarly found bidirectional causality among total electricity consumption, industrial electricity consumption, and real GDP for the period 1971-2006. This indicates a complex relationship where economic growth and electricity consumption mutually influence each other over time. Masih and Masih's earlier works (1996, 1997) might provide additional context or methodological insights into their findings, possibly relating to earlier studies on similar topics. Tang (2009) applied Error Correction Model (ECM) and Granger causality analysis to examine the causal relationship between electricity consumption, income, population, and FDI for the period of 1970-2005. The study concluded that there is bidirectional causality among electricity consumption, income, and FDI in the short run. This finding suggests that changes in electricity consumption, income levels, and foreign direct investment can influence each other mutually over relatively short periods, indicating the interconnected nature of these economic variables.

3. THE MODEL

The endogenous growth model is adopted to investigate the impact of energy and economic growth as earlier Stern (1991), Barro(1990), Helpmen(1992), and Romer (1990) used the same model. The basic endogenous production function is

$$Yt = At\, f(Kt, Nt) \quad (1)$$

Where Y, K and N are output (GDP), Capital & Labour respectively and A is the level of production efficiency or it is called total factor productivity (TFP). There is another factor which may have significant impact on growth, therefore the above equation may be written as

$$Yt = At\, f(Kt, Nt, EGt) \quad (2)$$

Where, EG is Electricity Supply, the equation 2 would be used to investigate impact of energy on economic growth. Mathematically, the model is as under;

$$Yt = At\, Kt^{\alpha}\, Lt^{\beta} EGt^{1-\alpha-\beta} \quad (3)$$

Where α and β and (1 – α – β) are share of Capital, labour and energy. The sum of Capital and Labour and energy is equal to 1 under the assumption of Constant Return to Scale. The equation (3) is can be converted into linear function by taking log and obtain elasticity of labour, capital and energy. The production function w.r.t time (t) and simplified as.

$$Ln\, Y = Ln\, At + \alpha\, LnK + \beta\, LNL + (1 - \alpha - \beta)\, LNEGt \quad (4)$$

Data from the Second Handbook of Statistics by the Statistics Division, Government of Pakistan for the year 2021 is utilized in this analysis. This comprehensive dataset encompasses various sectors including money and banking, balance of payments, national income, savings and investments, capital markets, and other key economic indicators of Pakistan. The dataset spans from 1950 to 2020, providing annual measurements for variables such as GDP and investment. Some sector-specific data covers periods less than a year. For this study, annual data will primarily be used, especially since macroeconomic indicators like GDP are reported annually. Specifically, the time series from 1981 to 2020 will be employed. There are various metrics to measure output (GDP), such as GDP per capita, GDP growth rates, and nominal or real GDP. Real GDP will be the focus of this study. There are several methods to measure labor input. Initially, one could consider the number of hours worked, but unfortunately, this data is not available to us. Another alternative is to use the number of years of schooling completed, which reflects the quality of the labor force and can serve as a proxy for labor inputs. Lastly, a more direct approach would be to utilize the number of workers in the total labor force as reported by the Economic Survey of the Finance Division, Government of Pakistan. For this particular study, we will use the third measure. Electricity generation will be employed as a proxy for energy.

4. RESULTS AND DISCUSSIONS

Table 1 provides a summary of descriptive statistics and regression results for the dependent variable Output (Y) and its associated variables: Capital (K), Labour (L), and Energy (EG). Capital (K) exhibits a mean value of 0.165, with a standard error of 0.044 and a t-value of 3.750, indicating statistical significance at the 1% level. This suggests that changes in capital significantly impact Output (Y) in the model. Labour (L) shows a mean value of 0.539, with a standard error of 0.258 and a t-value of 2.089, suggesting statistical significance at the 5% level. This indicates that variations in labor inputs also have a notable impact on Output (Y) in the regression model. Energy (EG) has a mean value of 0.296, a standard error of 0.166, and a t-value of 1.775, indicating statistical significance at the 10% level. This suggests that changes in energy usage contribute significantly to explaining variations in Output (Y). The Constant term in the model has a mean value of 0.672, with a standard error of 0.481 and a t-value of 1.395. However, it is not statistically significant at conventional levels, suggesting that the intercept does not significantly influence Output (Y) in this context. The R-Square value of 0.75 indicates that the model explains 75% of the variation in the dependent variable, Output (Y). This suggests a good fit of the model to the data, implying that Capital (K), Labour (L), and Energy (EG) collectively explain a substantial portion of the variation in Output (Y). Lastly, the F-test statistic of 4.42 is statistically significant at the 5% level. This indicates that at least one of the independent variables (Capital, Labour, or Energy) significantly affects Output (Y), providing overall support for the regression model's validity in explaining the variability in Output (Y) based on the included variables.

Table 1: Descriptive Statistics

Dependent Variable: Output (Y)			
Variables	Mean Value	Standard Error	t- value
Capital (K)	0.165	0.044	3.750*
Laboure (L)	0.539	0.258	2.089**
Energy (EG)	0.296	0.0.166	1.775***
Constant	0.672	0.481	1.395
R-Square	0.75	F -test	4.42*

Table 2 presents the results of Johansen's test for multiple co-integration vectors. The test assesses the co-integration relationships among the variables Y (Output), K (Capital), L (Labour), and EG (Energy). For the hypothesis r=1r = 1r=1 versus r>1r > 1r>1 using the trace statistic, the computed value λtrace=50.95858\lambda_{trace} = 50.95858λtrace=50.95858 exceeds the critical value 47.8561347.8561347.85613, indicating rejection of the null hypothesis r=1r = 1r=1 in favor of r>1r > 1r>1. This suggests the presence of at least one co-integrating vector among the variables. Similarly, for the hypothesis r≤1r \leq 1r≤1 versus r>1r > 1r>1, the computed value λtrace=31.73390\lambda_{trace} = 31.73390λtrace=31.73390 also exceeds the critical value 29.7970729.7970729.79707, confirming rejection of r≤1r \leq 1r≤1 in favor of r>1r > 1r>1. This further supports the presence of more than one co-integrating vector. The values under λmax\lambda_{max}λmax also provide insights into the maximum eigenvalue test. For r=1r = 1r=1 versus r=2r = 2r=2, the computed value 28.4206528.4206528.42065 is greater than the critical value 21.1316221.1316221.13162, supporting the presence of one co-integrating vector. The co-integrating vector matrix [Y,K,L,EG][Y, K, L, EG][Y,K,L,EG] shows the weights assigned to each variable in the co-integrating relationship. This matrix indicates that all variables are positively related to the co-integration vector, with Y having a weight of 1.00, suggesting that Output (Y) is the base variable in this relationship.

Table 2: Johansen Co-integration Test

Ho	H1			
λtrace		Λtrace	Critical Values	
r = 1	r > 1	50.95858	47.85613	
r ≤ 1	r > 1	31.73390	29.79707	
r ≤ 2	r > 2	15.31895	15.49471	
λmax Values				
r = 0	r = 1	29.24737	27.58434	
r = 1	r = 2	28.42065	21.13162	
r = 2	r = 3	10.43545	14.26460	
Co-integrating Vector	Y	K	L	EG
	1.00	0.804	1.04	0.76

5. CONCLUSIONS

The integration of economies into the global market, particularly since the establishment of the WTO, has intensified competition among nations seeking to expand their economic footprint internationally. This competitive environment drives

countries to pursue strategies aimed at achieving robust GDP growth. Efficient use of resources like labor and capital becomes crucial in this pursuit. However, alongside these traditional factors of production, energy emerges as a pivotal component essential for driving economic activities forward. Energy shortages pose significant challenges to sustained economic growth. Countries face the dual imperative of ensuring reliable energy supply while keeping costs manageable. High energy prices can inflate production costs across industries, affecting competitiveness and economic performance. Therefore, governments and industries alike prioritize investments in energy infrastructure and technologies that not only meet current demand but also support future growth aspirations. In conclusion, the quest for higher GDP growth requires nations to optimize their use of labor, capital, and energy resources. Balancing energy availability with affordability is critical for maintaining competitiveness in global markets and sustaining economic prosperity. This study delves into the intricate relationship between energy and economic growth using rigorous analytical tools spanning from 1972 to 2020. By employing unit root and co-integration techniques, the research identifies a robust long-term relationship among the variables studied. Notably, the empirical results underscore the significant positive impact of energy on economic growth, as evidenced by the positive signs observed in the G vector analysis. The findings suggest that energy plays a pivotal role as a fundamental input in driving economic activities forward. However, the study also highlights the detrimental effects of energy shortages on economic performance. In periods marked by acute energy deficits, economic activities are hampered, leading to a slowdown in overall economic growth. This underscores the critical importance of ensuring stable and sufficient energy supply to sustain economic development and mitigate adverse impacts on national economies. By examining these dynamics over nearly five decades, the study provides valuable insights into how energy policies and infrastructure investments can be optimized to enhance economic resilience and foster sustainable growth. Future research directions may explore policy interventions aimed at improving energy efficiency, diversifying energy sources, and promoting renewable energy adoption to further bolster economic stability and prosperity.

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