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Exploring the Dynamics Nexus of Energy Consumption, Economic Growth, Capital Stock, and Labor Force

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Abstract

The present study investigates the impact of energy consumption on real GDP, capital stock, and labor force using annual data from 1971 to 2017. The empirical analysis is conducted within the structural vector auto-regression framework. The findings from the SVAR model provide several key insights into the dynamic relationships among these variables. The results reveal that economic growth significantly increases the demand for the labor force, however, this increase is not sustainable over the long term. This suggests that while economic expansion initially boosts employment, the effect may diminish as the labor market reaches saturation or as technological advancements reduce the need for additional labor. Similarly, the study finds that other factors, such as capital stock and energy consumption, exhibit comparable patterns. Greater energy inputs are required to support new additions to the capital stock, indicating a strong interdependence between energy use and capital investment. This implies that as the economy grows and new capital is accumulated, there is a concurrent increase in energy demand to sustain the expanded production capacity. Furthermore, the analysis shows that exogenous shocks to capital stock and the labor force stimulate economic activity, but these effects are also temporary. This suggests that while sudden increases in capital and labor can boost GDP in the short term, the long-term sustainability of this growth is questionable without consistent improvements in productivity and efficiency. Rising capital stock is associated with higher demand for labor, reflecting the expansion of production activities within the economy. As businesses invest in more capital, they require additional workers to operate the new machinery and facilities, thus driving up employment levels. Based on these findings, the study recommends that the government should focus on stabilizing and enhancing the supply of energy. A reliable and affordable power supply is critical for sustaining economic growth. Ensuring a consistent energy supply will help support ongoing capital investments and maintain the operational capacity needed for economic expansion.

Keywords: Energy Consumption, Economic Growth, Capital Stock, Labor Force
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1. INTRODUCTION

The causal linkages between energy consumption and economic growth are crucial for policymakers due to their implications for policy formulation. The pioneering work of Kraft and Kraft (1978) established a unidirectional causal relationship from economic growth to energy consumption, laying the foundation for subsequent empirical studies on this topic (Apergis and Payne, 2009; Abosedra et al., 2009). This foundational research has spurred extensive investigation into how these two variables interact and influence one another, with significant policy ramifications. Understanding whether economic growth drives energy consumption or vice versa is essential for developing effective energy and economic policies. If economic growth leads to increased energy consumption, as Kraft and Kraft suggested, then policies aimed at economic expansion must also consider the corresponding rise in energy demand and the environmental impacts. Conversely, if energy consumption drives economic growth, as some later studies have suggested, ensuring a stable and sufficient energy supply becomes a critical focus for sustaining economic development. Apergis and Payne (2009) and Abosedra et al. (2009) extended this analysis by exploring these dynamics in different contexts and employing more sophisticated econometric techniques. Their studies often found varied results depending on the country or region in question, the time period analyzed, and the specific methods used. These diverse findings indicate that the relationship between energy consumption and economic growth can be complex and context-dependent, necessitating tailored policy approaches. For policymakers, these insights underline the importance of adopting a nuanced perspective when formulating energy and economic policies. Ensuring a balance between promoting economic growth and managing energy consumption is critical. This might involve investing in energy-efficient technologies, diversifying energy sources, and encouraging sustainable practices across industries. Additionally, understanding the specific causal relationship in their context can help policymakers anticipate future energy needs and implement strategies that support both economic and environmental objectives.

Understanding the relationship between energy consumption and economic growth is essential as energy consumption is considered a key driver of macroeconomic growth. However, the empirical literature has not provided conclusive evidence regarding the direction of causality between energy consumption and economic growth (Karanfil, 2009). This

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inconclusiveness highlights the complexity of the relationship and the influence of various factors that may differ across regions, periods, and methodologies. Karanfil (2009) emphasized the need for more comprehensive and context-specific studies to unravel the intricate dynamics between energy consumption and economic growth. While some studies suggest that economic growth leads to higher energy consumption, supporting the notion that as economies expand, their energy needs increase, others propose the reverse: that energy consumption is a fundamental driver of economic growth, implying that access to and consumption of energy resources are prerequisites for economic development. The lack of a definitive conclusion in the literature suggests that the relationship may be bidirectional and influenced by additional variables such as technological advancements, energy efficiency improvements, regulatory environments, and the energy mix of a country. For instance, countries heavily reliant on fossil fuels might experience different dynamics compared to those investing in renewable energy sources. Therefore, policymakers must consider these nuances when formulating strategies. Policies promoting economic growth should also focus on sustainable energy consumption patterns, emphasizing energy efficiency and the development of renewable energy sources to mitigate potential negative environmental impacts. Conversely, energy policies should consider the broader economic context, ensuring that energy supply and infrastructure investments support sustainable economic development. This dual approach requires a careful balance, tailored to the specific economic and energy profiles of each country, to foster a synergistic relationship between energy consumption and economic growth, ultimately leading to sustainable development. Policy formulation in the area of energy consumption and economic growth faces several challenges, as highlighted by Ozturk (2010) and Payne (2010). Karanfil (2009) emphasizes the importance of considering a wide range of potential variables in empirical research to avoid misleading causality relationships. The complexity and multifaceted nature of the relationship between energy consumption and economic growth require a comprehensive approach that integrates various economic, social, and environmental indicators. To address these challenges, recent studies have explored additional indicators such as labor employment, CO2 emissions, exports, urbanization, financial development, and foreign direct investment (Shahbaz et al., 2012; Shahbaz and Lean, 2012b; Ciarreta and Zarraga, 2010; Chandran et al., 2010; Lean and Smyth, 2010; Sadorsky, 2010; Tang, 2009). These studies aim to provide a more holistic understanding of the factors influencing the energy-economy nexus, recognizing that energy consumption and economic growth are influenced by a broader set of variables beyond the traditional metrics.

For instance, Shahbaz et al. (2012) and Shahbaz and Lean (2012b) have incorporated indicators like financial development and foreign direct investment to examine their impact on the energy-growth relationship. These studies suggest that financial markets and international capital flows play significant roles in shaping energy consumption patterns and economic growth trajectories. Similarly, Lean and Smyth (2010) and Sadorsky (2010) have investigated the role of urbanization and CO2 emissions, respectively, highlighting the environmental implications of energy use and the need for sustainable urban planning. The inclusion of these additional variables helps to capture the complex interplay between energy consumption, economic growth, and other critical factors. It also aids in identifying policy interventions that can promote sustainable development. For example, policies aimed at improving energy efficiency, promoting renewable energy sources, and encouraging investments in green technologies can help mitigate the environmental impact of economic growth while ensuring energy security. Moreover, understanding the role of exports and labor employment can inform trade and labor policies that support economic growth without exacerbating energy consumption and environmental degradation. By considering a wide range of indicators, policymakers can develop more targeted and effective strategies that balance economic development with sustainability goals. The integration of diverse variables in empirical research enriches the analysis of the energy-growth nexus, providing valuable insights for policymakers. It underscores the need for a multifaceted approach to policy formulation that considers the interconnectedness of economic, social, and environmental dimensions in achieving sustainable development.

The historical macroeconomic scenario in Pakistan presents a nuanced picture characterized by fluctuating real GDP growth rates and varying investment trends over the decades. During the 1980s, Pakistan experienced its highest real GDP growth rates, signaling a period of economic expansion and development. However, this growth trajectory saw a significant downturn in the 1990s, marked by lower growth rates, which could be attributed to various economic challenges and policy decisions during that period. One notable aspect is the stability of the fixed investment to GDP ratio during the 1980s and 1990s, indicating a consistent level of investment relative to the size of the economy. However, there was a noticeable decline in this ratio during the 2000s, suggesting a potential slowdown in investment activity or a shift in investment patterns during that period. The growth rate of the labor force, on the other hand, presents a mixed picture, with periods of negative growth observed during the 1970s, 1980s, and 2000s. This fluctuation in labor force growth could be influenced by various factors such as demographic changes, labor market dynamics, and economic policies affecting employment opportunities. A concerning trend highlighted by the GDP deflator is the persistent inflationary pressure observed over the years. The rising trend in the GDP deflator indicates a continuous increase in the overall price level, reflecting inflationary pressures within the economy. This inflationary trend could have significant implications for consumer purchasing power, business costs, and overall economic stability. Lastly, the analysis of energy intensity, as indicated by the energy consumption to GDP ratio, reveals a relatively stable pattern over the period under consideration. Despite fluctuations in economic growth and investment levels, the energy intensity of the economy remained consistent, suggesting a consistent relationship between energy consumption and economic output. The historical macroeconomic trends in Pakistan underscore the complex dynamics and challenges facing the economy, including fluctuations in growth rates, investment patterns, labor dynamics, inflationary

pressures, and energy consumption. Understanding these historical trends is crucial for policymakers and stakeholders to formulate effective strategies for sustainable economic development and address ongoing challenges.

2. METHODOLOGY

Structural vector autoregression (SVAR) serves as a fundamental tool for assessing the structural parameters within an econometric framework. The significance of these structural estimates lies in their robustness, as they are not susceptible to the Lucas critique. The Lucas critique, introduced by Sims (1980), raised concerns about the endogeneity of variables in econometric models, leading to the development of reduced form vector autoregression (VAR) models estimated using Ordinary Least Squares (OLS). Impulse responses (IRs) and variance decompositions provided by the VAR system illustrate the dynamic interactions among variables. The estimation of structural VAR typically involves two stages. In the first stage, the reduced form VAR is estimated, capturing the relationships among variables without imposing structural constraints. In the second stage, the parameters of the reduced form VAR are utilized to derive the structural parameters. However, this approach encounters an identification problem, as the number of structural parameters exceeds those of the reduced form. Addressing this challenge requires imposing reasonable restrictions on the parameters to ensure identification. The structural parameters derived from SVAR estimation offer valuable insights for applied research and policymaking. By capturing the underlying structural relationships among key variables, these parameters provide guidance for understanding the dynamic interactions within the economy and formulating effective policy responses. In the present study, four variables are considered: energy consumption, real GDP, capital stock, and labor force. Annual data spanning from 1971 to 2019 is utilized, with all values expressed in real terms and denominated in millions with 2000 as the base year. The data is sourced from reputable sources such as the World Development Indicators and the International Financial Statistics, ensuring reliability and accuracy in the analysis.

3. RESULTS

The structural vector autoregression (SVAR) impulse responses provide insights into the dynamic interactions among key variables, including real GDP, capital stock, labor force, and energy consumption. These impulse responses, denoted by D(LG), D(LK), D(LL), and D(LENC) respectively, are analyzed over a 10-year time horizon. All the time series data are expressed in first differences, indicating that they are integrated of order one based on Schwarz Bayesian (SBC) criteria. Additionally, there is no evidence of any cointegrating relationship among the variables, suggesting that they do not share long-term equilibrium relationships. In response to a one standard deviation shock to real GDP, there is a notable increase in the demand for labor force. However, this rise is not permanent and tends to diminish after a period of two years. Similarly, the shock to real GDP also positively impacts capital stock and energy consumption, indicating an increase in both variables in the short term. However, like the labor force, this effect is not sustained over the long term. These findings suggest that shocks to real GDP have significant but transitory effects on labor force, capital stock, and energy consumption. Understanding these dynamics is crucial for policymakers and analysts in formulating appropriate economic policies and forecasting future trends. The observed rise in both capital stock and energy consumption following a shock to real GDP reflects their complementary relationship in the production process. However, this increase is temporary, and both variables revert to their mean levels after approximately two years. This suggests that while there is an initial surge in capital stock and energy consumption to support increased economic activity, this effect is not sustained over the long term. One noteworthy implication of these findings is the confirmation of the existence of the growth hypothesis in Pakistan.

The positive relationship between capital stock and energy consumption indicates that as the economy expands and capital investment increases, there is a corresponding rise in energy usage. This underscores the importance of energy as a critical input in the production process and highlights the need for sustainable energy policies to support economic growth. Furthermore, the unexpected rise in capital stock leads to an increase in real GDP growth, which persists for a period of approximately two years. However, this growth is temporary, and real GDP eventually reverts back to its mean level. Concurrently, there is also an immediate increase in the labor force in response to this shock. This suggests that additional labor units are required to accommodate the expansion in business activity and to operate the new machinery associated with the increased capital stock. The temporary nature of the rise in the labor force, returning to its mean relatively quickly compared to real GDP, suggests a faster convergence of the labor force. This phenomenon can be attributed to the presence of inertia in real GDP, which delays its mean reversion. In contrast, the labor force adjusts more rapidly, reflecting its responsiveness to changes in economic conditions. The increase in capital stock also has implications for energy demand in the short run. Although there is initially no significant rise in energy consumption, demand for energy begins to increase with a lag of three years. This delayed response underscores the time it takes for increased capital stock to translate into higher energy usage, reflecting the intricate dynamics of the production process.

Variance decomposition analysis provides further insights into the drivers of variation in real GDP. Initially, real GDP itself accounts for the majority of its variance, indicating the dominance of internal factors in driving economic fluctuations. However, after four years, the labor force becomes the primary contributor to variance in real GDP, surpassing the contributions of energy consumption and capital stock. This shift highlights the evolving dynamics of the economy over time, with labor force fluctuations playing a more prominent role in shaping economic variability in the medium to long term. The variance decomposition analysis further highlights the dynamics of labor force, energy consumption, and capital stock. The

presence of inertia in the labor force is evident, with labor force fluctuations primarily driven by its own variations. Real GDP accounts for a substantial portion of the variation in labor force, underscoring the intertwined relationship between economic output and labor force dynamics. In contrast, capital stock and energy consumption contribute relatively less to the variance in the labor force, reflecting their limited influence on labor force fluctuations. Consistent with the impulse response analysis, the variance decomposition results indicate a lack of significant response between labor force and energy consumption. Labor force variations have minimal impact on energy consumption, and vice versa, highlighting the relative independence of these variables in driving each other's fluctuations. Over time, the composition of variation changes, with capital stock and energy consumption exchanging their positions in terms of their contributions to variance. Initially, capital stock exhibits substantial self-variation, suggesting a high degree of internal dynamics within the capital stock variable. However, the role of real GDP becomes more prominent in driving variations in energy consumption over time, reflecting the evolving relationship between economic output and energy demand. These findings provide valuable insights into the dynamics of labor force, energy consumption, and capital stock, shedding light on their interactions and contributions to economic variability over time.

Table 1: Variance Decomposition Approach

Panel: A

	real GDP				Labor Force			
Period	Shock1	Shock2	Shock3	Shock4	Shock1	Shock2	Shock3	Shock4
1	100.00	0.00	0.00	0.00	9.77	5.59	84.64	0.00
2	92.11	0.01	7.88	0.00	19.67	7.56	72.44	0.33
3	54.91	5.13	14.24	25.72	25.92	6.59	66.49	1.00
4	50.10	5.15	12.89	31.87	24.08	6.95	67.95	1.01
5	31.99	4.31	38.74	24.97	22.17	6.01	59.75	12.07

Panel: B

	Energy Consumption				Capital Stock			
Period	Shock1	Shock2	Shock3	Shock4	Shock1	Shock2	Shock3	Shock4
1	0.20	3.92	4.45	91.43	36.57	63.43	0.00	0.00
2	40.46	1.34	38.77	19.43	52.21	45.65	0.58	1.57
3	35.47	12.27	31.61	20.65	49.24	38.17	7.84	4.75
4	34.02	10.10	26.17	29.71	48.84	36.98	9.92	4.25
5	38.36	6.04	37.64	17.96	37.19	28.49	7.12	27.19

In Panel A, the analysis focuses on the dynamics between real GDP and the labor force. It reveals that Shock1 initially holds the highest influence on real GDP, suggesting a significant impact of this particular shock on economic fluctuations. However, as time progresses, the dominance of Shock1 diminishes, giving way to Shock3, which gradually becomes the primary driver of variability in real GDP. This shift indicates a changing pattern in the underlying factors affecting economic output over time. Regarding the labor force, Shock3 consistently maintains a substantial influence across all periods, highlighting its persistent impact on labor market dynamics. Panel B delves into the relationship between energy consumption and capital stock. Here, Shock4 emerges as the predominant factor influencing energy consumption variability throughout the analyzed periods. This finding suggests that specific factors represented by Shock4 significantly drive fluctuations in energy usage over time. Conversely, in the case of capital stock, Shock1 exhibits the highest influence in the initial periods, gradually declining in significance over time. This indicates that certain factors represented by Shock1 play a more substantial role in shaping capital accumulation dynamics in the earlier stages, with their influence diminishing as other factors come into play. The variance decomposition approach offers valuable insights into the relative importance of different shocks in explaining the variability of economic variables. By identifying the key drivers of fluctuations, policymakers and analysts can better understand the underlying mechanisms driving economic dynamics and formulate appropriate policy responses.

4. CONCLUSION AND POLICY IMPLICATIONS

Addressing energy-related challenges is indeed a global concern, and Pakistan is no exception. The complexities and interdependencies within the energy sector make policymaking in this area particularly challenging. In Pakistan, where energy shortages and inefficiencies have long hindered economic growth and development, understanding the underlying causal relationships is crucial for formulating effective policies to address these issues. The present study aims to contribute to this endeavor by providing empirical evidence of the causal relationships within Pakistan's energy sector. By analyzing the dynamics between various energy-related variables, such as energy consumption, economic growth, and labor force dynamics, the study seeks to uncover the mechanisms driving energy demand and its implications for broader economic performance. Such empirical evidence is invaluable for policymakers in Pakistan, as it can inform the design and implementation of targeted

interventions to enhance energy efficiency, promote renewable energy sources, and mitigate the impact of energy shortages on economic activity.

By identifying causal relationships and understanding their implications, policymakers can develop more informed and effective strategies to address Pakistan's energy challenges and foster sustainable economic growth. The findings from the SVAR analysis shed light on the dynamic interactions between economic growth and energy consumption in Pakistan. While economic growth stimulates the demand for labor force, capital stock, and energy consumption, the response to such shocks is not sustainable in the long term. This suggests that while economic expansion may temporarily boost energy demand, it also underscores the need for energy conservation measures to ensure sustainable development. Furthermore, the observation that an increase in economic activity requires additional energy inputs to support the expansion of capital stock highlights the critical importance of energy efficiency and conservation strategies in Pakistan. Implementing measures to promote energy efficiency across various sectors can help mitigate the strain on energy resources, reduce dependence on fossil fuels, and promote environmental sustainability. These findings provide valuable insights for policymakers in Pakistan, emphasizing the importance of prioritizing energy conservation efforts alongside economic development initiatives. By adopting proactive measures to enhance energy efficiency and promote sustainable energy practices, Pakistan can effectively address its energy challenges while fostering long-term economic growth and environmental resilience.

The SVAR analysis reveals that an exogenous shock to the capital stock in Pakistan stimulates economic activity temporarily. This temporary increase in economic activity leads to a rise in the demand for labor force, as expanding production activities require more workers to operate and manage the increased capital stock. Furthermore, the surge in capital stock also exerts upward pressure on energy demand in the short run. While the initial increase in energy consumption is substantial, the demand for energy continues to rise for up to three years following the shock to capital stock. This indicates that the expansion of capital stock has significant implications for energy consumption patterns in Pakistan, highlighting the need for effective energy management strategies to ensure sustainability and resilience in the face of increased energy demand. The temporary nature of the increase in economic activity and the subsequent rise in energy demand underscores the importance of addressing energy efficiency and conservation measures in Pakistan. As the economy experiences growth driven by increases in capital stock, there is a corresponding need for enhanced energy management practices to mitigate the strain on energy resources and infrastructure. Moreover, the findings suggest that while capital stock expansion can stimulate short-term economic activity, sustaining this growth requires comprehensive energy planning and investment in renewable and efficient energy technologies. Failure to address the surge in energy demand resulting from capital stock expansion could lead to challenges such as energy shortages, increased energy costs, and environmental degradation. Therefore, policymakers in Pakistan must prioritize the development and implementation of policies that promote sustainable energy practices, encourage investment in renewable energy sources, and enhance energy efficiency across sectors.

By doing so, Pakistan can achieve long-term economic growth while minimizing its reliance on finite energy resources and mitigating the environmental impact of energy consumption. Addressing the energy-intensive nature of Pakistan's production structure is crucial for sustainable economic development. The government's focus on ensuring affordable and reliable power supply to all sectors of the economy is essential for fostering growth and competitiveness. Initiatives to tackle issues such as line losses and power theft can significantly enhance the efficiency and effectiveness of the energy sector. Implementing prudent accountability measures to reduce preventable losses can free up resources that can be reinvested in generating additional power capacity. Furthermore, transitioning towards a deregulated energy sector can promote market efficiency, attract investment, and encourage innovation in energy production and distribution. By adopting a comprehensive approach that combines infrastructure improvements, regulatory reforms, and investment in renewable energy sources, Pakistan can address its energy challenges while unlocking new opportunities for economic growth and development. Attracting private investment in power generation and distribution is indeed critical for addressing Pakistan's energy challenges. The fragmentation and multiplicity of government departments in the energy sector create inefficiencies and hinder effective policymaking and implementation. Consolidating these departments into a single ministry or energy authority could streamline operations, reduce transaction costs, and improve coordination. Pakistan's abundant coal reserves and hydroelectric potential offer significant opportunities for power generation. However, realizing this potential requires creating an enabling environment to attract foreign investment. This involves implementing reforms to improve transparency, strengthen regulatory frameworks, and provide incentives for private sector participation. By fostering a conducive investment climate and promoting public-private partnerships, Pakistan can unlock its energy resources, enhance energy security, and support economic growth and development. Collaboration between government agencies, private sector stakeholders, and international partners will be essential to achieve these objectives.

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