INTERNATIONAL JOURNAL OF
SOCIAL SCIENCES BULLETIN
ISSN: (E) 3007-1917 (P) 3007-1909

Volume 4, Issue 4, 2026

ENERGY CONSUMPTION AND SECTORAL ECONOMIC GROWTH IN PAKISTAN: EVIDENCE FROM DISAGGREGATED SECTORAL DATA

Nosheen Nasir[1], **Tahir Mahmood**[*2]

[1]*PhD Scholar, Quaid-i-Azam University, Islamabad, Pakistan*
[*2]*Associate Professor, Quaid-i-Azam University, Islamabad, Pakistan*

[1]nosheen.32211002@eco.qau.edu.pk, [*2]tamahmood@qau.edu.pk

Corresponding Author: *
Tahir Mahmood

DOI: https://doi.org/10.5281/zenodo.20018731

Received	Accepted	Published
07 March 2026	14 April 2026	30 April 2026

ABSTRACT

This paper looks into the sectoral effect of energy consumption on the economic growth in Pakistan by considering the agriculture, industrial and services sectors between 1980 and 2023. Through an augmented Cobb Douglas production formulation, the analysis uses capital stock, labor force participation, and sector-specific energy consumption as well as other variables. The empirical study is undertaken with the Autoregressive Distributed Lag (ARDL) methodology in order to embrace both the short run and the long run effect. The results establish the existence of long run association between energy use and sectoral output. The findings however indicate that there is a positive and statistically significant effect of energy consumption (EC) on economic growth (EG) in industrial and agriculture sector, and a negative and statistically significant effect of energy consumption on economic growth in services sector, which depicts structural inefficiencies, inefficient energy supply, and high energy prices in Pakistan. Capital formation and labor input play a positive role in increasing the sectoral growth but are limited by the shortage of energy. The paper highlights the need to have sector-specific energy policies, enhanced energy efficiency, and institutional reforms in order to facilitate sustainable and inclusive economic growth in Pakistan.

1. Introduction

Energy consumption (EC) has been identified as one of the key factors in economic growth (EG) and structural transformation especially in the developing economies where the production processes are very much energy intensive. Classical and neoclassical growth theories are based on the central importance of capital accumulation and labor as the critical determinant of output (Solow, 1956; Mankiw et al., 1992), and newer extensions also underscore the essential role of energy as a complementary factor of production that increases the productivity of both capital and labor (Halicioglu, 2009; Chandio et al., 2019). In that regard, insufficient access to the contemporary, affordable and trustworthy energy, which is referred to as energy scarcity, is a restrictive bind on economic action, capital formation and technological advancement. The nations with a history of energy scarcity find themselves in a vicious cycle whereby lack of energy supply leads to low productive capacity, reduced competitiveness, and ultimately low long-run growth potential (Bacon and Kojima, 2016; Karekezi et al., 2012).

It is based on this theoretical backdrop that it becomes necessary to empirically investigate the ways in which EC can be converted into economic performance in various economies. Although theory predetermines energy as a key factor in the production process, in reality, performance can be different because of economic structure, endowment of resources, and development stages. It encourages a more in-depth examination of the empirical literature to discern the nature and reliability of the energy-growth relationship (Abbasi et al., 2020). The interdependence of EC and EG has been the focus of much scholarly attention and there has been an overall consensus that energy and economic activity are highly interdependent, although the direction and intensity of the effect may vary according to the country and stage of development. There is empirical evidence in the developed and developing economies which tends to indicate a positive long-run relationship between EC and EG (Eggoh et al., 2011; Belke et al., 2011; Fei et al., 2011; Dai et al., 2022; Muço et al., 2021).

At the same time, nonlinearities and threshold effects have been documented, suggesting that beyond certain levels, additional energy use may generate diminishing or even adverse growth effects due to inefficiencies, structural rigidities, or environmental constraints (Lee and Chang, 2007). These conflicting results highlight the need to consider the context-specific and disaggregated analysis when considering the energy- growth nexus. In the case of developing economies, the EC growth effects are all the more critical since small access to modern energy services limits the process of industrialization, modernization of the agricultural sector and services sector growth. The impact of energy deprivation on future output is a decline in productivity or the increase in production costs and deterrence in investments both domestic and foreign (Dagoumas and Kitsios, 2014; Piwowar, 2022). In response to these issues, global development agenda pays great attention to guaranteeing world access to affordable and clean energy as part of Sustainable Development Goal 7, as well as to achieve sustained and inclusive economic growth as part of Sustainable Development Goal 8 (UNDP, 2021). To meet these aims, there is need to increase the supply of energy as well as to learn the role, the use of energy plays in economic performance of various productive sectors.

Though this literature gives a valuable understanding of the distributional and social aspects of energy availability, it mostly isolates the macroeconomic and sectoral growth outcomes of patterns in EC. On the macro level, the available studies on Pakistan have been on the aggregate relationship between EC and EG in many cases, it has been found that there is a positive relationship (Razaq et al., 2023; Abbasi et al., 2020). Nonetheless, estimates at the national level could mask a high level of heterogeneity between the sectors. The energy intensity, the technological structure, and the reliance on continuous power supply of agriculture, industry and services are drastically different. As an example, the industrial manufacturing in Pakistan is very energy consuming and power outage sensitive (Qazi and Raza, 2022), as agriculture becomes more dependent on mechanization and irrigation by use of energy (Malik et al., 2020; Kaygusuz, 2011). Services sector especially those that are ICT-intensive need to have consistent and good quality electricity that will support productivity and innovation (Modi et al., 2005). Though these are structural differences, there is little systematic sector specific evidence of the impact of EC on EG in Pakistan.

In Pakistan, there is a good reason why such an investigation should be undertaken. The energy crises in the country have been recurrent with shortages in supply, frequent power outages, and high energy prices, which have created huge macroeconomic and sectoral losses (Aftab, 2014; Javed et al., 2016). Empirical studies document widespread energy deprivation at the household level: approximately 71% of rural and 29% of urban households lack reliable access to modern energy services (Awan et al., 2013), as over half of all households are multidimensionally energy poor, and experience deprivations in access to electricity, clean cooking fuels, and reliability of supply (Qurat-ul-Ann and Mirza, 2021; Awan and Bilgili, 2022).

The existing literature primarily examines the relationship between EC and EG either at an aggregate level (Sharif et al., 2023) or within individual sectors (Raza et al., 2025), largely ignoring the simultaneous sectoral heterogeneity across agriculture, industry, and services. Additionally, there is a dearth of literature to combine EG with sector-specific structural, technological, and institutional variables in an energy-augmented neoclassical model of a developing economy such as Pakistan. As a result, there remains limited empirical evidence on how energy and non-energy determinants jointly shape differential sectoral growth dynamics in the long run.

This research is aimed to address this critical gap by analysing empirically the sectoral role of EC on EG in the agriculture, industrial and services sectors of Pakistan between the years 1980 and 2023. To expand on an augmented Cobb-Douglas production model, the analysis has included EC as a fundamental factor of production alongside capital stock and labor, with the analysis controlled by other sector specific factors. Autoregressive Distributed Lag (ARDL) methodology is used to obtain short-run and long-run dynamics of a process to be able to evaluate the temporal changes and long-run relationships of equilibrium.

The main objective of this study is to empirically investigate the short-run and long-run impacts of EC and sector-specific economic, technological, and structural factors on sectoral EG in Pakistan, by employing an energy-augmented neoclassical production framework that explicitly accounts for heterogeneity across the agriculture, industrial, and services sectors.

The research offers a number of contributions in the existing literature. First, it brings the energy-growth nexus further by moving the emphasis away, however, on aggregate outcomes to a sectorally disaggregated viewpoint, and thereby revealing heterogeneous growth responses to EC by productive sectors. Second, it offers time series evidence of long horizon and more than forty years history, which gives a solid foundation on which to make inference on structural dynamics within the Pakistani economy. Thirdly, incorporating EC into Cobb Douglass production function, the paper reconciles the macroeconomic growth analysis.

The motivation for undertaking this study arises from the growing recognition that EC has become one of the most critical constraints to sustainable EG in developing economies, particularly in Pakistan. Although it is the production factor that is central, energy is commonly considered as an aggregate input, which ignores the fact that not all sectors of the economy, such as agriculture, industry, and services, are equally dependent on energy and responsive to changes in energy. The economy of Pakistan has suffered chronic energy unavailability, escalating energy prices, and organizational ineffectiveness, which have impacted on energy intensive industries and undermined the general performance of growth. In this regard, it is imperative to understand the role of sector-specific EC in contributing to EG in order to develop useful energy and development policies. The research is thus significant because it goes past the aggregate analysis and offers a sectoral approach to the energy-growth nexus, which enables one to understand the impact of energy allocation, efficiency, and availability on the performance of various sectors in an economy in a more detailed manner. The study will provide useful information to policy makers in prioritizing energy investments, eliminating growth bottlenecks and aiding sustainable structural change in the Pakistani economy by identifying the differential sectoral effects.

Policy-wise, sector-specific energy policies that value the differentiated energy needs and productivity responses between agriculture, industry, and services will be anticipated to yield the results. Such evidence is required during the development of consistent policies that would assist in boosting energy efficiency, ensuring supply reliability, and making Pakistan shift towards inclusive and sustainable EG. The rest of this paper is organized in the following way. Section 2 will offer a thorough literature review of the existing research on the association between EC and economic growth with emphasis placed on sector dynamics. Section 3 presents the empirical model, sources of data, variable construction, and estimation strategy used during the analysis. The ARDL model empirical findings of the agriculture, industry, and services sectors of Pakistan are presented and discussed in section 4. Lastly, the study is concluded in Section 5 which summarizes the significant findings and provides the policy implications and suggestions on future research.

2. Review of Literature

Establishing a connection between rising energy use and EG is important for many projects in the energy sector. Projects that explore oil or gas deposits or improve the capacity of power generation, transport, or distribution (including expanding access) are meant to facilitate higher energy production and consumption as one of their effects. There is a connection between these energy-oriented projects and poverty reduction if increasing energy use increases EG in an economy and higher EG reduces poverty to the extent that it does. Therefore, the fact that there is a connection between EG and EC suggests advantages beyond those experienced by the direct recipients of the increasing energy supply (Bacon and Kojima, 2016). Eggoh et al., (2011) investigate the link between EC and EG in African countries. They highlight that economic expansion necessitates sufficient EC while also acknowledging that increased energy use can fuel economic progress. Similarly, Belke et al., (2011) employed cointegration analysis to assess whether EC and EG move together in the long run, even if they fluctuate in the short term. Besides the long-run relationships found in literature, short-run relationships between EC and EG should be considered with great attention as well. Over the short-term, the changes in energy consumption might not be directly reflected in the corresponding changes in economic output because of structural inflexibility, adjustment costs, and long lags in technological adjustment. Time is frequently needed to absorb the energy shocks, redistribute resources, and change production processes in economic systems, and consequently temporary short-run disequilibrium relationships may arise. These short-term variations demonstrate the need to draw the line between short-term and long-term impacts when examining the energy-growth nexus, especially in developing economies whereby institutional and market inefficiencies can further magnify transitional relationships.

Moreover, Mehrara, (2007) explored the specific relationship between EC and EG in nations that rely heavily on oil exports, noting that boom-and-bust cycles in oil prices can lead to economic instability. Fei et al., (2011) find a positive long-term relationship between EG and EC, meaning that as China's economy expands, its energy needs also rise. Lee and Chang, (2007) investigated the relationship between EC and EG in Taiwan and find that when EC is low, it can contribute to EG. However, after a certain point (the threshold), further increases in EC have minimal or even negative effects on EG. In the same vein, Dai et al., (2022) and Muco et al., (2021) also hold that EC and EG have a positive relationship that is strong. That is, the higher EC the higher the EG will accelerate and vice versa. Rufael, (2014) researched the causal relationship between electricity consumption and EG in 15 transition economies and yields one-way correlation between EC and EG. The same was concluded by Çetintaas, (2016). Due to its effects on EG, Abbasi et al., (2020) will unveil an uneven influence of renewable and non-renewable energy on growth in the case of Pakistan, which may imply that energy sources do not have the same effect on EG. On the same note, Razaq et al., (2023) explore the effects of EC on the EG of Pakistan through econometric analysis and find that there is a strong positive correlation between EC and economic development. In addition, Bashir, (2025) assesses the effects of oil price volatility and the uptake of renewable energy on the economic development of Pakistan using time series analysis and emphasizes the bi-directional aspect of the energy price fluctuations and the renewable energy transitions in economic development. According to Lee and Chang, (2007), it is stated that beyond some extent (the threshold) any further increase in EC in Taiwan does not have significant or even negative impact on EG. Anna et al., (2019) discover that EG enhances residential EC to greater incomes.

Baz et al., (2020) findings implicitly support that energy inefficiencies and structural rigidities can offset growth benefits, particularly in sectors where energy use is poorly managed. This limitation reinforces the need for sector-specific analysis, as undertaken in the present study, to better understand how EC differentially affects agriculture, industry, and services in Pakistan. Parween et al., (2020) affirm that energy use is generally growth-supportive, but the varying magnitudes of impacts and reliance on aggregate time-series analysis limit insights into sectoral energy-growth heterogeneity and environmental considerations, underscoring the need for more sector-specific and disaggregated assessment as pursued in your manuscript. Munir and Nadeem, (2022) employ a disaggregated sectoral framework to assess how different types of EC (electricity, gas, petroleum) influence EG across Pakistan’s agriculture, industrial, and services sectors, finding that the energy– growth link varies significantly by sector, with industrial growth most responsive to EC.

These results indicate that strong sectoral asymmetries exist in the energy growth nexus, indicating that economic output does not respond to energy inputs equally across sectors. Such differences may be explained by production structure, intensity of energy as well as level of technology adoption in each industry.

Specifically, industries where capital intensity and mechanization is more intense are more likely to have stronger dependence on EC, but comparatively traditional industries may have weaker or more indirect interdependences. This supports the claim that sector-specific nexus are needed to reflect the diverse and heterogeneous quality of the energy-growth nexus.

The observation that Nadeem and Munir, (2016) made that energy use has non-homogeneous impacts with industry exhibiting the highest positive correlation whereas agriculture and services have less meaningful or no connection whatever. Despite the significant sectoral distinctions emphasized in the study, its application of conventional co-integration techniques and aggregate energy indicators could lead to nonlinearities and dynamic interdependencies that play an essential role in explaining the diverse energy-growth trajectories. Khan et al., (2020) examine the correlation between the two variables EC and EG in Pakistan and discover that greater energy consumption is highly linked to greater economic activity demonstrating that energy is a major factor in growth in output. Nevertheless, the study considers EC at a macro level and primarily on the growth and emissions across the entire economy, which restricts its capacity to describe the different impacts of energy on the performance of individual sectors.

2.1 Theoretical Framework: Energy Consumption and Economic Growth

The relationship between economic growth (EG) and energy consumption (EC) has been the focus of significant development in the economic theory, beyond an implicit treatment in classical models, to a direct and significant treatment in modern growth models. The classical economists of the early 19th century, including Adam Smith and David Ricardo, theorized economic development as a factor of land, labor, and capital, with natural resources, including implicitly defined energy, being a limiting factor of production.

This classical view ultimately constrains EG through the scarcity of resources, which means that lack of energy can constrain industrial and agricultural production. Nevertheless, one of the major shortcomings of classical theory is that it does not explicitly model the energy as an independent and measurable input, thus undervaluing its dynamic contribution to contemporary production systems. Formal integration of factors of production came with neoclassical theory of growth, notably by Robert Solow whose Solow Growth Model came up with a production function which accumulated capital, labor, and exogenous technological advancements (Solow, 1956). Although the original model did not explicitly consider energy, later extensions realized energy as a key input that is complementary to capital and labor. Stern (2000) said that without energy being included in the functions of production, the model would be miss-specified because without energy, economic activity at any point of production cannot happen. The empirical results of augmented neoclassical models indicate that, productivity can be greatly boosted by EC, especially in energy-consuming industries like manufacturing. The neoclassical assumption of exogenous technological changes limits its explanatory power, however, because it does not explain how the availability of energy per se can transform innovation and efficiency change. Endogenous growth theory developed by Paul Romer and Robert Lucas Jr. overcomes this limitation by internalizing technological advances, a factor of human capital, innovation and knowledge spillovers (Romer, 1990; Lucas, 1988).

Here, the role of energy is more dynamic as it is not only an input but a catalyst of technological advancement and structural transformation. Regular and low-cost energy can help modernize industries, conduct research and development projects and enhance the efficiency of human capital. Conversely, energy crises such as those that have been experienced in the history of Pakistan can interfere with the production process, reduce its efficiency, and drag down the growth in the long run. Recent theoretical advancements also expand on this perception and suggest that the use of energy is intrinsically tied with thermodynamic constraints and that economic systems are unable to expand without energy flows (Stern, 2011). An endogenous model, however, gives a more comprehensive explanation, however, where the role of innovation may still be overemphasized in situations where structural limitations like inadequate energy infrastructure are still in play.

In parallel with these theoretical developments, empirical literature of the nexus between energy and growth began with an early study by Kraft and Kraft, (1978) which discovered a causal relationship between EC and EG in the United States. The study formed the foundation of four competing propositions; the growth hypothesis, the conservation hypothesis, the feedback hypothesis and the neutrality hypothesis. Subsequent research as by Apergis and Payne (2010) provided some evidence on the notion of a two way causality in most economies which may suggest that EC and EG are each other reinforcing. However, the lack of consensus in the literature suggests a contextually determined character of this relationship, which is predetermined by such factors as the economic regime, energy policy, and the level of development.

The shift of aggregating analysis to sectoral analysis is one of the significant changes in the literature. Initial studies to a great extent viewed EC as a homogenous variable by ignoring the heterogeneity of sectors. Recent research has demonstrated that EC is very sensitive in sectors with the industrial sector exhibiting the highest energy elasticity of output, then agriculture and services. Such a difference is particularly crucial in the example of Pakistan, where the energy-consuming industrial sector is disproportionately affected by energy shortages. Other researches such as those by Jamil and Ahmad (2010) have revealed that sectoral EC does not have the same effects on the EG and therefore disaggregated analysis is significant. Considering these theoretical and empirical advances, this research follows a merged approach that merges classical resource limits, neoclassical production theory, and endogenous growth processes. Energy is conceptualized as (i) a resource in scarcity, (ii) direct factor of production and (iii) a source of technological advancement. This combined approach enables a more delicate explanation of the impact of sectoral EC on EG, especially in an energy-starved economy such as Pakistan. The framework includes sector-specific dynamics to fill critical gaps in the literature and offer a more credible basis of empirical analysis and policy development.

2.2 Energy consumption and sectoral growth:

Energy is acknowledged to directly contribute to the value-added and also indirectly contribute by complementing the capital and labor inputs. Thus, the energy-augmented neoclassical production functions have emerged (Tugcu et al., 2012; Adewuyi and Awodumi, 2017), within an energy-augmented neoclassical production framework where energy complements capital and labor in generating output. In the agricultural sector, energy enables mechanization, irrigation, fertilizer application, and post-harvest processing, thereby increasing land and labor productivity. Energy plays a key role in the industrial sector, driving manufacturing, which produces machinery, production lines, and logistic systems, maximizing capital use and overall factor productivity. In the services industry, infrastructure, information and communication technologies, transportation, and systems of service delivery are facilitated by energy, which contributes indirectly to efficiency and output. Therefore, energy is not only a direct input to value added production but also a complementary element which increases the productivity of other inputs making it a major determinant of sustained sectoral growth and the overall economic growth.

3. Model and Methodology

Based on the theoretical backgrounds of the classical, neoclassical and endogenous growth theories, this research makes use of an augmented production model to analyze how energy consumption (EC) affects the economic growth (EG) in Pakistan. Although classical economists like Adam Smith and David Ricardo pointed out that resource constraints define output, the modern growth theory, especially the Solow Growth Model created by Robert Solow, offers a formal framework in which output is a variable of capital and labor, and technology is an exogenous variable (Solow, 1956). But later empirical and theoretical work, led by Stern, (2000) has come to the view that energy is an essential input into the production process and should be directly included in growth models. In this regard, this paper builds on the traditional neoclassical model by introducing energy as a specific factor of production via the Cobb Douglas production model:

To investigate how energy consumption (EC) effects economic growth (EG) we illustrate our model is based on the conventional neoclassical production function. Thus we consider the following general Cobb-Douglas production function: The economic model,

$$Y_t = A^* L_t^{\beta 1} K_t^{\beta 2} E_t^{\beta 3} \quad (1)$$

The econometric model to examine the relationship between energy consumption and economic growth is following:

$$Y_t = A^* L_t^{\beta 1} K_t^{\beta 2} E_t^{\beta 3} e^{ut} \quad (2)$$

$$Y_t = \beta_1 + \beta_2 L_t + \beta_3 K_t + \beta_4 E_t + \varepsilon_t \quad (3)$$

The independent and dependent variables of a regression have a deterministic linear relationship when expressed in the logarithmic form of the Cobb-Douglas production function. A number of recent advances in this literature recognise the importance of several demographic, social, technological, and economic elements for a country's economic progress (Mankiw et al., 1992; Doganalp et al., 2021). An econometric model of the Cobb-Douglas production function type is suggested below to examine the impact of EC and other neoclassical elements on Pakistan's EG (Kubik, 2010). The parameters β_i's 2, 3, 4 represent the responsiveness of EG to changes in energy usage, capital stock and labor respectively. This model represents an effort to examine the complex interplay between EG, EC, capital formation, and labor force. By analysing data, researchers can gain insights into the factors driving a nation's EC and potentially develop evidence-based policies to achieve sustainable growth

$$Y_t^{Ind} = \beta_1 + \beta_2 L_t + \beta_3 K_t + \beta_4 E_t + \varepsilon_t \quad (4)$$

$$Y_t^{Agr} = \beta_1 + \beta_2 L_t + \beta_3 K_t + \beta_4 E_t + \varepsilon_t \quad (5)$$

$$Y_t^{Ser} = \beta_1 + \beta_2 L_t + \beta_3 K_t + \beta_4 E_t + \varepsilon_t \quad (6)$$

The dependent variables Y_t^{Ind}, Y_t^{Agr}, Y_t^{Ser} denote EG of industrial, agriculture and services sectors respectively. Similarly, E, K and L represent the energy consumption, capital stock, labor force respectively in the industrial, agriculture and services sectors. The specified econometric model is followed in accordance with Ejaz et al. (2016) with the inclusion of additional relevant variables.

$$Y_t^{Ind} = \beta_1 + \beta_2 L_t + \beta_3 K_t + \beta_4 E_t + \beta_5 Trd_t + \beta_6 FDI_t + \beta_7 HC_t + \beta_8 GI_t + \varepsilon_t \quad (7)$$

Where Y_t^{Ind} represents industrial output, measured by industrial value added at constant 2015 U.S. dollars, obtained from the World Development Indicators (WDI). L_t denotes labor input, measured by labor force participation in the industrial sector (in thousands), sourced from the International Labour Organization (ILO), Pakistan Economic Survey. K_t refers to capital stock, proxied by capital used in the industrial sector, measured in million Pakistani rupees at current market prices, with data obtained from the State Bank of Pakistan (SBP). E_t represents energy consumption (EC), measured as EC by the industrial sector, sourced from the Pakistan Energy Year Book.

Furthermore, Trd_t represents the trade openness that is equal to total trade (Percentage of GDP). According to Lee, (2020) trade openness enhances industrial sector growth by expanding access to international markets, advanced intermediate inputs, and capital goods, which improves scale economies, capacity utilization, and total factor productivity. Greater exposure to foreign competition also incentivizes technological upgrading and cost efficiency in domestic industries. Pakistan's industrial growth is affected by trade openness through a number of channels including monetary policy, fiscal policy, and foreign direct investment (Umer and Alam, 2013).

FDI is the foreign direct investment which is equal to net inflows as percentage of GDP and are derived using the world development indicators (WDI). Foreign direct investment (FDI) stimulates industrial sector growth by bringing in capital resources, facilitating technology transfer, and improving management practices, which together raise productivity and output in manufacturing and related industries (Bush, 2017).

HC_t represents human capital in terms of the literacy rate in cities and the data is obtained by the Pakistan Bureau of Statistics (PBS). The inclusion of human capital, proxied by the literacy rate, is directly justified by the augmented Solow growth model. Human capital enhances industrial sector growth by improving the skills, education, and capabilities of the workforce, which increases labor productivity, facilitates technology adoption, and supports innovation in manufacturing and related industries (Li and Gao, 2024).

Finally, GI_t is the government index of the industrial sector, which is proxied by the Quantum Index of Large-Scale Manufacturing (base year), which was provided by the Pakistan Bureau of Statistics (PBS). According to Babasanya et al., (2021) there is a need for the government to intensify efforts towards improving the extent people can challenge her power and authority because these play significant roles in the development level of industrial growth. This econometric model specification follows Salam et al., (2018) with the inclusion of additional relevant variables.

$$Y_t^{Ser} = \beta_1 + \beta_2 L_t + \beta_3 K_t + \beta_4 E_t + \beta_5 ICT_t + \beta_6 PDIF_t + \beta_7 INN_t + \beta_8 FDI_t + \beta_9 Trd_t + \varepsilon_t \quad (8)$$

Where Y_t^{Ser} is the output of services sector in constant 2015 as the value added in the services at constant U.S. dollars which are found in the World Development Indicators (WDI). L_t denotes labor input, measured by labor force participation in the services sector (in thousands), with data sourced from the International Labour Organization (ILO) and the Pakistan Economic Survey (PES). K_t refers to capital stock, proxied by capital used in the services sector, measured in million Pakistani rupees at current market prices, and obtained from the State Bank of Pakistan (SBP). E_t represents energy consumption, measured as energy consumption by the services sector, sourced from the Pakistan Energy Year Book.

In addition, ICT service exports are measured as a percentage of total service exports based on the balance of payments data and are obtained from the International Monetary Fund (IMF). Sarangi and Pradhan, (2020) argue that ICT infrastructure acts as a growth-augmenting input by enhancing total factor productivity (TFP) through efficiency gains, technological diffusion, and reduction in information asymmetries. The paper provides evidence that ICT development facilitates innovation spillovers, improves factor allocation, and strengthens human capital effectiveness, thereby exerting a statistically significant and positive impact on long-run EG.

$PDIF_t$ captures per-worker productivity differences across sectors, measured as the ratio of services sector output to services sector employment. Lee and Mckibbin, (2018) analyze service sector productivity differentials and show that variations in productivity across service sub-sectors have significant implications for aggregate EG in Asia. The study finds that higher productivity in modern, knowledge-intensive services (such as finance, ICT, and business services) contributes disproportionately to GDP growth through efficiency gains and inter-sectoral spillovers.

INN_t represents innovation, proxied by “Development expenditure on science and technology”, with data sourced from the Pakistan Ministry of Finance. Innovation in the service sector significantly improves economic performance by enhancing productivity and competitiveness. Cainelli et al., (2004) finds that innovation increases value added and firm-level efficiency in services, which in turn contributes to aggregate EG through spillover effects to other sectors.

FDI_t denotes foreign direct investment, measured as net inflows as a percentage of GDP. Hlavacek and Bal-Domanska, (2016) find that FDI exerts a positive and statistically significant impact on EG by augmenting capital formation and enhancing total factor productivity. The paper highlights that FDI is a technological transfer, managerial knowledge, and innovation spillovers channel through which it enhances the productivity of local firms. Trd_t is the openness to trade, which is calculated as a proportion of total trade to GDP; both the variables are found in the World Development Indicators (WDI).

Openness to trade has a positive impact on economic growth as it enhances the allocation of resources, market access, and the competitive pressures in the developing countries. The study argues that international trade enhances productivity through learning-by-exporting effects and access to higher-quality intermediate inputs and technologies (Makki and Somwaru, 2004).

$$Y_t^{Agr} = \beta_1 + \beta_2 L_t + \beta_3 K_t + \beta_4 E_t + \beta_5 CA_t + \beta_6 WA_t + \beta_7 FC_t + \beta_8 SD_t + \beta_9 CD_t + \varepsilon_t \quad (9)$$

Where Y_t^{Agr} represents agricultural sector output, measured by agricultural value added at constant 2015 U.S. dollars, obtained from the World Development Indicators (WDI). L_t represents the input of labor, which includes labor force participation in agricultural sector (in thousands) and the sources of these data are International Labour Organization (ILO) and Pakistan Economic Survey (PES). K_t is capital stock, capital that is utilized in agricultural sector in million Pakistani rupees at current market prices and acquired by State Bank of Pakistan (SBP). E_t is the energy consumption whereby the agricultural sector is used as the source of the entitlement of EC, obtained through the Pakistan Energy Year Book. Additionally, CA_t represents cropped area, which is in thousands hectares but the figures were sourced out of the Pakistan Bureau of Statistics (PBS). Ranade, (1980) argues that changes in cropped area allocation significantly influence agricultural output and productivity through improved land-use efficiency and optimal factor utilization. The study shows that expansion of cropped area under high-yield and cash crops raises value added in agriculture, which contributes to economic growth via higher rural incomes, employment generation, and stronger forward and backward linkages with non-agricultural sectors.

WA_t is an acronym that refers to the availability of water in the form of total annual withdrawal of freshwater in billion cubic meters, which are obtained through the world development indicators (WDI). According to Elliott et al., (2014), irrigation water availability constitutes a key constraint on agricultural production, thereby indirectly shaping EG. This paper demonstrates that the constraints of water resources due to climate change can decrease crop yields and enhance the variability of production and that it may have spill-over consequences on prices and economic stability. FC_t is the consumption of fertilizers. It uses the percentage of fertilizer use of fertilizer production, and the World Development Indicators (WDI) provide the information. McArthur and McCord, (2017) argue that fertilizer use is a factor behind EG, as it enhances agricultural productivity which is a critical source of structural change in developing economies. In the study, the increase in the yield of crops, especially through the increase in the use of inputs, especially fertilizers, increases incomes of the farm and creates spillover effects on the economy due to increased demand and capital accumulation.

SD records better distribution of seeds, and data was obtained at the State Bank of Pakistan (SBP). Improved seed distribution plays a crucial role in enhancing agricultural productivity by increasing crop yields and resilience through better genetic quality and adaptability. Sah, (2014) highlights that access to high-quality seeds enables farmers to achieve higher output levels with the same level of inputs, thereby raising farm incomes and contributing to rural economic activity.

Lastly, CD_t signifies credit to the agricultural sector, which is in the form of agricultural credit disbursement and the data is received through the State Bank of Pakistan (SBP). According to Hartarska et al. (2015), the distribution of agricultural credit enhances EG by relaxing liquidity constraints faced by rural producers, enabling higher investment in inputs and technology. Improved access to credit increases farm productivity and income, which stimulates local demand and generates multiplier effects in rural economies. This is a model specification in line with Rehman et al. (2019).

The order of integration of the variables before estimating the short-run and long-run dynamics is needed to make certain that the econometric technique is appropriate. The outcomes of the unit root tests (including ADF and PP; see table 1) show that the variables that are included in the model are integrated at mixed orders, i.e., some variables are stationary i.e. I(0), and others are stationary after first differencing I(1). Notably, no two-order at once I(2) integration of the variables is done, which is one of the main conditions of the use of the Autoregressive Distributed Lag (ARDL) modeling methodology. With such a combination of integration orders, the ARDL bounds testing methodology, designed by Pesaran et al. (2001) is deemed as the most appropriate method to be used in the current study. The ARDL model has a number of strengths: it can be used regardless of whether regressors are purely I(0), purely I(1), or cointegrated; it can be made to give efficient and unbiased estimates even in small samples; and it can be used to estimate both short-run and long-run relationships in a single reduced-form equation. In addition, the ARDL model can successfully solve the problems of endogeneity and serial correlation by selecting the lag appropriately. Therefore, based on the outcomes of the pre-estimation unit root tests and the methodological strengths of the ARDL approach, this study employs the ARDL model to examine the dynamic relationships among the variables. The general ARDL specification is presented in Equations (10–12) below.

$$\begin{aligned}
&\Delta\ln\left(\mathrm{Y}_{\mathrm{t}}^{\mathrm{Ind}}\right) = \alpha + \textstyle\sum_{i=1}^{n1} \beta_{\mathrm{i}}\, \Delta\ln(\mathrm{Y}_{\mathrm{t-i}}^{\mathrm{Ind}}) + \sum_{i=0}^{n2} \gamma_{\mathrm{i}}\, \Delta\ln(\mathrm{L}_{\mathrm{t-i}}) + \sum_{i=0}^{n3} \delta_{\mathrm{i}}\, \Delta\ln(\mathrm{K}_{\mathrm{t-i}}) + \sum_{i=0}^{n4} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{E}_{\mathrm{t-i}}) + \\
&\textstyle\sum_{i=0}^{n5} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{Trd}_{\mathrm{t-i}}) + \sum_{i=0}^{n6} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{FDI}_{\mathrm{t-i}}) + \sum_{i=0}^{n7} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{HC}_{\mathrm{t-i}}) + \sum_{i=0}^{n8} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{GI}_{\mathrm{t-i}}) + \\
&\theta_1 \ln\left(\mathrm{Y}_{\mathrm{t-1}}^{\mathrm{Ind}}\right) + \theta_2 \ln(\mathrm{L}_{\mathrm{t-1}}) + \theta_3 \ln(\mathrm{K}_{\mathrm{t-1}}) + \theta_4 \ln(\mathrm{E}_{\mathrm{t-1}}) + \theta_5 \ln(\mathrm{Trd}_{\mathrm{t-1}}) + \theta_6 \ln(\mathrm{FDI}_{\mathrm{t-1}}) + \\
&\theta_7 \ln(\mathrm{HC}_{\mathrm{t-1}}) + \theta_8 \ln(\mathrm{GI}_{\mathrm{t-1}}) + \varepsilon_{\mathrm{t}} \qquad (10)
\end{aligned}$$

$$\begin{aligned}
&\Delta\ln\left(\mathrm{Y}_{\mathrm{t}}^{\mathrm{Ser}}\right) = \alpha + \textstyle\sum_{i=1}^{n1} \beta_{\mathrm{i}}\, \Delta\ln\left(\mathrm{Y}_{\mathrm{t-i}}^{\mathrm{Ser}}\right) + \sum_{i=1}^{n2} \gamma_{\mathrm{i}}\, \Delta\ln(\mathrm{L}_{\mathrm{t-i}}) + \sum_{i=1}^{n3} \delta_{\mathrm{i}}\, \Delta\ln(\mathrm{K}_{\mathrm{t-i}}) + \sum_{i=1}^{n4} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{E}_{\mathrm{t-i}}) + \\
&+ \textstyle\sum_{i=1}^{n5} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{ICT}_{\mathrm{t-i}}) + \sum_{i=1}^{n6} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{PDIF}_{\mathrm{t-i}}) + \sum_{i=1}^{n7} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{INN}_{\mathrm{t-i}}) + \sum_{i=1}^{n8} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{FDI}_{\mathrm{t-i}}) + \\
&\textstyle\sum_{i=1}^{n9} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{Trd}_{\mathrm{t-i}}) + \theta_1 \ln\left(\mathrm{Y}_{\mathrm{t-1}}^{\mathrm{Agr}}\right) + \theta_2 \ln(\mathrm{L}_{\mathrm{t-1}}) + \theta_3 \ln(\mathrm{K}_{\mathrm{t-1}}) + \theta_4 \ln(\mathrm{E}_{\mathrm{t-1}}) + \theta_5 \ln(\mathrm{ICT}_{\mathrm{t-1}}) + \\
&\theta_6 \ln(\mathrm{PDIF}_{\mathrm{t-1}}) + \theta_7 \ln(\mathrm{INN}_{\mathrm{t-1}}) + \theta_8 \ln(\mathrm{FDI}_{\mathrm{t-1}}) + \theta_9 \ln(\mathrm{Trd}_{\mathrm{t-1}}) + \varepsilon_{\mathrm{t}} \\
&\qquad (11)
\end{aligned}$$

$$\begin{aligned}
&\Delta\ln(\mathrm{Y}_{\mathrm{t}}^{\mathrm{Agr}}) = \alpha + \textstyle\sum_{i=1}^{n1} \beta_{\mathrm{i}}\, \Delta\ln(\mathrm{Y}_{\mathrm{t-i}}^{\mathrm{Agr}}) + \sum_{i=0}^{n2} \gamma_{\mathrm{i}}\, \Delta\ln(\mathrm{L}_{\mathrm{t-i}}) + \sum_{i=0}^{n3} \delta_{\mathrm{i}}\, \Delta\ln(\mathrm{K}_{\mathrm{t-i}}) + \sum_{i=0}^{n4} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{E}_{\mathrm{t-i}}) + \\
&\textstyle\sum_{i=0}^{n5} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{CA}_{\mathrm{t-i}}) + \sum_{i=0}^{n6} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{WA}_{\mathrm{t-i}}) + \sum_{i=0}^{n7} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{FC}_{\mathrm{t-i}}) + \sum_{i=0}^{n8} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{SD}_{\mathrm{t-i}}) + \\
&\textstyle\sum_{i=0}^{n9} \lambda_{\mathrm{i}}\, \Delta\ln(\mathrm{CD}_{\mathrm{t-i}}) + \theta_1 \ln\left(\mathrm{Y}_{\mathrm{t-1}}^{\mathrm{Agr}}\right) + \theta_2 \ln(\mathrm{L}_{\mathrm{t-1}}) + \theta_3 \ln(\mathrm{K}_{\mathrm{t-1}}) + \theta_4 \ln(\mathrm{E}_{\mathrm{t-1}}) + \theta_5 \ln(\mathrm{ICT}_{\mathrm{t-1}}) + \\
&\theta_6 \ln(\mathrm{CA}_{\mathrm{t-1}}) + \theta_7 \ln(\mathrm{WA}_{\mathrm{t-1}}) + \theta_8 \ln(\mathrm{FC}_{\mathrm{t-1}}) + \theta_9 \ln(\mathrm{SD}_{\mathrm{t-1}}) + \theta_{10} \ln(\mathrm{CD}_{\mathrm{t-1}}) + \varepsilon_{\mathrm{t}} \\
&\qquad (12)
\end{aligned}$$

4. Results and Discussion

4.1 Unit root tests

To identify unit roots and establish the level of integration for the three variables, we initially carry out unit root test using methods such as Augmented Dickey-Fuller (Dickey and Fuller, 1981) and Phillips & Perron test. As unit root tests are sensitive to different lag structures, we utilized the Schwartz Information Criterion for lag selection. The null hypothesis of ADF in our study was that the series had a unit root. Economic growth and capital which are stationary at level. The series of EC and labour is stationary at first difference. Table 1 displays the results of these tests. The existence of a unit root was determined using the unit root test. In contrast to the alternative hypothesis, which holds that the series is stationary, the null hypothesis asserts that the series is non-stationary.

Table 1: Results of Unit Root Tests

	Augmented Dickey Fuller Test			Phillips Perron Test		
Variables	Level	1st difference	2nd difference	Level	1st difference	2nd difference
Economic growth (Agriculture)	-0.016	-1.278	-	-0.016	-1.278***	-
Economic growth (Industrial)	-0.025**	-	-	-0.025**	-	-
Economic growth (Services)	-0.015**	-	-	-0.015**	-	-
Energy consumption (Agriculture)	-0.208**	-	-	-0.208**	-	-

Energy consumption (Industrial)	-0.090	-0.934***	-	-0.090	-0.934***	-
Energy consumption (Services)	-0.043**	-	-	-0.033	-1.393***	-
Capital (Agriculture)	-0.018	-1.004***	-	-0.018	-1.004***	-
Capital (Industrial)	-0.018	-0.010***	-	-0.018	-0.010***	-
Capital (Services)	-0.013	-1.189***	-	-0.013	-1.189***	-
Labor (Agriculture)	-0.023	-1.185***	-	-0.023	-1.185***	-
Labor (Industrial)	-0.172	-2.111***	-	-0.172	-2.111***	-
Labor (Services)	-0.055**	-	-	-0.022	-1.216***	-
Foreign Direct Investment	-0.223**	-	-	-0.223**	-	-
Human capital	-0.092**	-	-	-0.092**	-	-
Trade	-0.222**	-	-	-0.222**	-	-
Government Index	-1.153	-0.728**	-	-1.153	-0.728**	-
ICT	-0.112	-1.308***	-	-0.112	-1.308***	-
Productivity Difference	-0.056	-1.441***	-	-0.048	-1.441***	-
Innovation	0.011	-0.598***	-	0.244**	-	-
Water Availability	-0.055	-2.274**	-	-0.055	-2.274**	-
Cropped Area	-0.128**	-	-	-0.128**	-	-
Fertilizer Consumption	-0.455***	-	-	-0.455***	-	-
Seeds Distribution	-0.146	-1.609*	-	-0.074	-1.609*	-
Credit Distribution	-0.004	-4.212*	-	-0.004	-4.212*	-

* **Indicates probability value (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)**

4.2 ARDL Results

Energy has been seen as one of the main contributors of economic growth (EG) in the 21st century. Energy use and EG have a strong connection since the increased rates of production growth result in increased energy consumption (EC) (Wang et al., 2022; Sarwar et al., 2025). Efficient use of energy leads to growth of the economy (Halicioglu, 2009). According to the ARDL results (Table 2), EC yields a positive and statistically significant impact on the growth of the industrial sector in Pakistan in all the models, meaning energy-led growth hypothesis is validated (Chandio et al., 2019). In the foreign direct investment and trade openness have positive effect on the industrial growth as illustrated by Khan (1980), that in the aftermath of the year 1958 and until mid-sixties the heavy foreign inflows alongside the liberal monetary and fiscal policies provided a very favorable investment environment in Pakistan and spawned a tremendous industrial activity. Human capital is also regarded as a significant engine of the sustainable industrial development, along with these economic variables. By making investments in the human capital that creates scientifically and technically sound human resource, competitive industrial growth environment is created as well as the appeal of the local investments to foreign investors. Then, the industrial growth is preconditioned by the investment in human capital in terms of education and vocational trainings, as well as effective spending on healthcare (Samouel and Aram, 2016). Such an observation indicates the nature of the manufacturing base in Pakistan that is highly energy intensive and thus the continuity of industrial performance is highly dependent on the availability of sufficient, low cost and stable energy supplies. The factual observation shows that when energy consumption increases, industrial production is boosted, on the other hand, it has been observed that when energy consumption decreases, there is a reduction in industrial production (Baz et al., 2019). Long-run economic development and sustainability are inseparable without efficient management of energy sources (Eggoh et al., 2011), whereas consistent energy shortages, frequent outages, and disruptions of supply still limit the performance of the industry, increase the operating costs, and diminish the attractiveness of the investment (IBA, Pakistan, 2023; Fatima and Ali, 2023; Federation of American Scientists, 2024). The outcomes herein highlight the fact that energy consumption is one of the key elements that drive the growth of industrial sector in Pakistan. Capital has a positive and significant impact on the industrial growth, which supports PIDE, (2023) and Umair et al., (2024), who have noted that modernized infrastructure and physical capital create a positive impact on the productivity and output, especially in combination with the stable energy supply. Trade also has a positive contribution to industrial output, which validates the results of Qayyum et al., (2018) and Rahim et al., (2023), where both domestic and international trade contribute to the better performance of the sector. The impact of foreign direct investment (FDI) on industrial growth is positive as it is in line with Umer and Alam, (2013) and Mehmood et al., (2025), showing that FDI inflows enhance technology transfer, capital accumulation, and productivity. The value of human capital is positive (Manzoor et al., 2025), which proves that human skills improve the productivity and efficiency of the industry. Conversely, government index has a negative and significant impact, as claimed by Rehman, (2025), which implies that an ineffective governance system, regulatory inefficiencies, or policy ambiguity can impede industrial growth and decrease sectoral growth. As a group, these control variables demonstrate that a set of factors such as capital, trade, human capital and FDI determine the growth of industries whereas governance constraints could adversely influence the performance of sectors.

Table 2: ARDL Results (Industrial Sector)

	M1	M2	M3
Variable	**Coefficient (t-stat)**	**Coefficient (t-stat)**	**Coefficient (t-stat)**
Long run Results			
Economic Growth	-0.197 (-1.607)	-0.361*** (-3.708)	-0.642*** (-6.092)
Labor	-0.002 (-0.081)	0.046** (-1.696)	0.100 (1.512)
Capital	0.071 (1.307)	0.153*** (3.487)	0.235*** (5.322)
Energy Consumption	0.021 (0.718)	0.051** (2.200)	0.131*** (4.586)
Trade	-	-0.002 (-1.651)	0.006*** (2.578)
Foreign Direct Investment	-	-0.0003 (-0.045)	0.002 (-0.251)
Human Capital	-	-	0.133 (0.340)
Government Index	-	-	-0.021***

			(-4.017)
Short run Results			
Δ Economic Growth	-	-0.200 (-1.442)	-0.243** (-2.066)
Δ Labor	-	-	0.015 (0.452)
Δ Capital	-	-	-
Δ Energy Consumption	0.084** (1.912)	-	-
Δ Trade	0.209 (1.542)	0.003** (1.889)	0.009*** (4.381)
Δ Foreign Direct Investment	-	-	-0.024** (-1.960)
Δ Human Capital	-	-	1.300** (3.544)
Δ Government Index	-	-	0.027*** (3.285)
Adjusted R-squared	0.997	0.997	0.998
F-statistic	2173.08***	2179.5***	1643.9***
Durbin-Watson stat	2.157	1.933	2.539
ECM	17.49	7.49	13.48
LM (F-statistics)	1.009	0.977 (-1.651)	0.445 (2.578)
CU	S	S	S
CU.Q	S	S	S

*** Indicates probability value (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)**

The ARDL results (Table 3) demonstrates that the effect of EC on the growth of the services sector is negative and statistically significant both in the short-run and the long-run estimates (M1–M3). This implies that low or inconsistent energy supply would disadvantage productivity, decrease working hours and increase operation costs, especially in the urban and semi-urban regions where uninterrupted energy supplies are critical to service provision and operations involving information technology and communication. These data are consistent with those obtained by Modi et al., (2005) and Sadath and Acharya, (2017), who underline that power outages and unstable electricity limit the abilities of service-oriented companies. Likewise, Zia and Khan, (2025) emphasize that economic contributions made by service sectors (finance, healthcare, and education) are slowed down by energy limitations. On the whole, these findings indicate that access to energy is a decisive factor with regard to sustainable development of the services sector in Pakistan. The positive and significant influence of capital on the development of the services sector is constant, which confirms the role of investment in infrastructure and equipment as a major factor of productivity. Trade has a positive and significant impact on output, which justifies Javed and Khan, (2024), meaning that, with higher domestic and foreign trade, sectoral performance is improved. The productivity difference has a negative impact on the growth of the sector, unlike Siddique (2022), which argues that efficiency discrepancies between firms lead to the decline in total output. There is a positive significant relationship between innovation and growth (Zia and Khan, 2025), proving that the technology development and new service models promote productivity. Foreign direct investment (FDI) gives a significant effect in line with Nadeem et al., (2025) whereas ICT has negative effect on output and that insufficient power supply in

ICT-intensive operations can restrain service delivery and productivity. All these findings emphasize the fact that the growth of services sector is not only based on capital, trade and the innovation that needs to be applied but also reducing inefficiencies, improving the level of FDI, and providing stable energy to carry out ICT activities.

Table 3: ARDL Results (Services Sector)

	M1	M2	M3
Variable	**Coefficient (t-stat)**	**Coefficient (t-stat)**	**Coefficient (t-stat)**
Long run Results			
Economic Growth	-0.008 (-0.212)	-0.011 (-0.258)	-0.244*** (-3.739)
Labor	0.100 (1.295)	0.057 (0.441)	0.111 (1.281)
Capital	0.0009 (1.654)	0.0009 (1.487)	0.0004*** (4.353)
Energy Consumption	-0.082** (-2.369)	-0.082** (-2.097)	-0.117*** (-3.234)
Trade	-0.082** (-2.082)	-0.086** (-2.059)	0.050 (0.896)
Productivity Difference	-	-11.62 (-0.429)	-129.3*** (-3.711)
Innovation	-	-0.0003 (-0.017)	0.033*** (3.859)
Foreign Direct Investment	-	-	-0.014** (-2.929)
ICT	-	-	-0.0009** (-2.199)
Short run Results			
Δ Economic Growth	-	-	-
Δ Labor	-	-	-
Δ Capital	0.0004*** (3.328)	0.0008*** (3.069)	0.0008*** (4.737)
Δ Energy Consumption	-	-	-
Δ Trade	0.113** (2.380)	0.111*** (2.076)	-
Δ Productivity Difference	-	-	45.90** (2.204)
Δ Innovation	-	-	0.019** (2.188)
Δ Foreign Direct Investment	-	-	0.0004 (0.078)
Δ ICT	-	-	0.0003 (0.455)
F-statistic	9513.1***	29.63***	6266.2***
Durbin-Watson stat	1.866	1.960	2.639
ECM	60.4	7.49	27.2
LM (F-Statistics)	0.320	0.024	0.324

CU	S	S	S
CU.Q	S	S	S

*** Indicates probability value ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$)**

The ARDL findings have shown that the agricultural sector of Pakistan is positively and statistically significant to the EC both in the short and long-run estimates (Table 4). This highlights the fact that availability of the energy in a reliable way improves productivity, lowers the cost of production and makes agricultural production sustainable. This result is similar to those by Liu et al., (2024), who emphasize the role of energy accessibility in rural communities that depend on agriculture, and Malik et al., (2020) who state that the lack and instability of energy supply compel the use of traditional and less-efficient methods, increase the cost of production, and reduce production. Moreover, Kaygusuz, (2011) highlights that adequate energy is the key to the transformation of the rural poverty cycle and underdevelopment, and Raza et al., (2020), Hayat et al., (2019), and Padda and Hameed, (2018) also remind that the reasons why renewable energy sources, and solar energy, in particular, can help to secure better irrigation and productivity levels are that the agricultural sector will become more independent and self-reliant. These findings indicate clearly that the consumption of energy is a sensitive factor in the growth and development of agriculture in general in Pakistan. Capital demonstrates an impact that is positive and significantly high, which means that investments in infrastructure and machinery increase the output of sectors, which confirms Ahmad et al., (2016), who state that the primary sector in the GDP and employment is agriculture. In the short-term, labor has a positive impact, which confirms the fact provided by USDA (2022) about the role of human capital in raising productivity. Cropped area has a positive and significant impact on output that is in line with Khan and Jinnah, (2016), and this is influenced by the use of larger and well-managed cultivated land. The effect on water availability is positive, which is consistent with Naeem and Sulehri, (2019) as sufficient irrigation and water resources lead to the improvement of crop yields. Lastly, the consumption of fertilizers is significantly positive, which proves to be in favor of Kashif et al., (2025), which confirms that the use of inputs in a manner that optimizes their use enhances the productivity of agriculture. Collectively, these control variables reinforce that agricultural growth depends on a combination of physical inputs, land management, water resources, and labor allocation.

Table 4: ARDL Results (Agriculture Sector)

	M1	**M2**	**M3**
Variable	**Coefficient (t-stat)**	**Coefficient (t-stat)**	**Coefficient (t-stat)**
Economic Growth	0.147** (2.102)	-0.006 (-0.095)	0.074 (0.296)
Labor	0.0008*** (0.0009)	0.0008*** (0.000)	0.0009** (0.000)
Capital	-299.0 (-0.478)	671.5 (0.884)	2656.8 (1.298)
Energy Consumption	57.87*** (0.0008)	0.0009*** (0.000)	0.0004*** (0.000)
Cropped Area	-	0.0004*** (0.000)	0.0003*** (0.000)
Water Availability	-	0.0001*** (0.000)	-0.0001 (0.000)
Fertilizer Consumption	-	-	0.0006*** (0.000)
Seeds Distribution	-	-	0.001***

			(0.000)
Credit Distribution	-	-	0.001*** (0.000)
Short run Results			
Δ Economic Growth	-0.281 (-1.682)	0.0009** (0.000)	-0.365** (0.000)
Δ Labor	0.0003*** (0.0009)	-0.0001*** (0.000)	0.001*** (0.000)
Δ Capital	2833.0 (1.622)	6017.3*** (0.000)	7528.3*** (2.903)
Δ Energy Consumption	0.0009*** (0.0008)	0.0002*** (0.000)	0.0009*** (0.000)
Δ Cropped Area	-	-	-
Δ Water Availability	-	0.0005*** (0.000)	-0.0006*** (0.000)
Δ Fertilizer Consumption	-	-	0.0008*** (0.000)
Δ Seeds Distribution	-	-	-
Δ Credit Distribution	-	-	0.0001*** (0.000)
Adjusted R-squared	0.996	0.996	0.996
F-statistic	1421.7***	1201.4***	801.2***
Durbin-Watson stat	1.962	2.280	2.122
ECM	5.99	8.87	0.0004*** (0.000)
LM (F-statistics)	0.177	0.118	4.53
CU	S	S	S
CU.Q	S	S	S

*** Indicates probability value (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)**

5. Conclusions

This paper investigated the sectoral effect of energy consumption (EC) on the economic growth (EG) in Pakistan using an ARDL model and using annual data covering 1980-2023. Leaving the largely aggregated literature behind, the analysis adopted a sectorally disaggregated Cobb Douglas production model of the agricultural, industrial, and neo-production sector and thus providing more disaggregated information about the way in which the dynamics of energy underpin productive performance at major sectors of the economy. The empirical results have shown that there is an evident heterogeneity in the growth response to the consumption of energy in industries. EC has a positive and statistically significant impact on the growth of the industrial and agricultural sectors, proving the energy-led growth hypothesis in the energy intensive sectors. The services sector, conversely, has shown a negative significant correlation with EC implying that any inefficiency in EC, inability to supply energy reliably, and increase in the cost of energy can outweigh the productivity improvement of greater EC in service-based and ICT-intensive processes. Taken together, these findings suggest that although energy availability is a very important production enabler, growth impacts are highly sector-dependent and dependent on efficiency, reliability and the quality of institutional settings. Besides EC, capital formation is also a strong growth driver in all sectors and emphasizes the need to have long-term investment in infrastructure and productive capacity. Trade openness, human capital, innovation and foreign direct investment are also positive contributors in the selected sectors and weak governance and productivity differentials inhibit growth performance. The results emphasize that energy policy should not work alone but have to be supported by other structural and institutional changes. Policy-wise, the findings lead to a sector-differentiated energy policy. In the case of agriculture, the proliferation of decentralized renewable energy solutions, especially solar-powered irrigation and off-grid systems would be beneficial in terms of enhancing mechanization, lowering the cost of production, and bolstering the livelihoods of the rural population. To remain competitive and to encourage long-term investment, grid stability, rationalization of prices of energy, and increased investment in cleaner and more efficient energy technologies are necessary in the industrial sector. For the services sector, the emphasis should shift toward improving energy efficiency, ensuring uninterrupted electricity supply for ICT-intensive activities, and promoting digital infrastructure supported by reliable power systems.

The research adds to the existing literature through the availability of both long-term and short-term sectoral data on energy-growth nexus in one of the largest developing economies with no adequate energy supply. However, there are still certain shortcomings. The discussion is based on the national level sectoral data that can conceal the significant difference among the regions. Future studies might build on this framework with provincial or district-level data, multidimensional measures of energy access, affordability, and reliability, and investigate how renewable energy adoption, climate change, and sectoral growth interact.

All in all, the above evidence indicates that the sustainable growth opportunities in Pakistan are highly dependent on the enhancement of the accessibility as well as the effective use of energy. This goal can be attained through well-coordinated policies comprising energy planning and industrial development, agricultural modernization, and services-sector digitalization. This kind of integrated approach is essential to the cause of inclusive growth and fulfilling the long-term sustainable development objectives of the country.

Figure 1

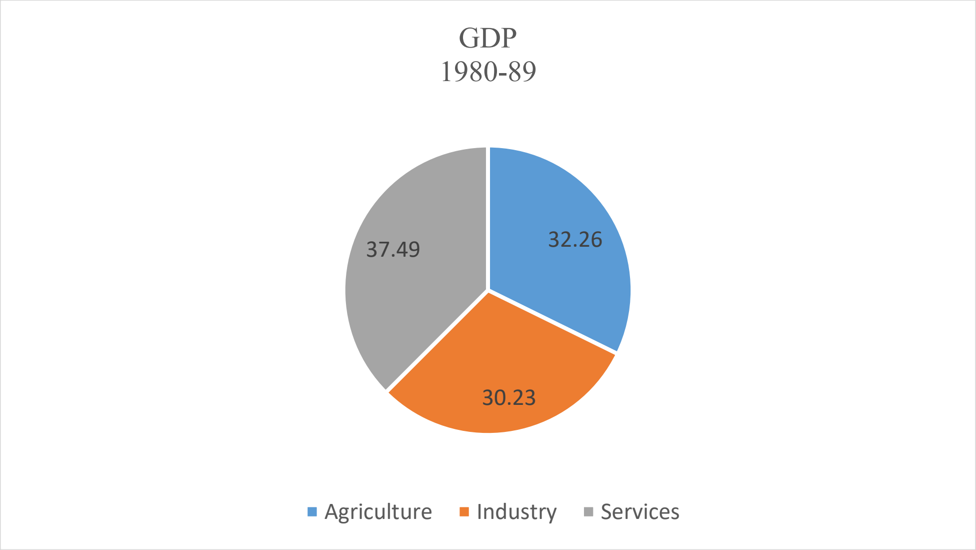


Figure 2

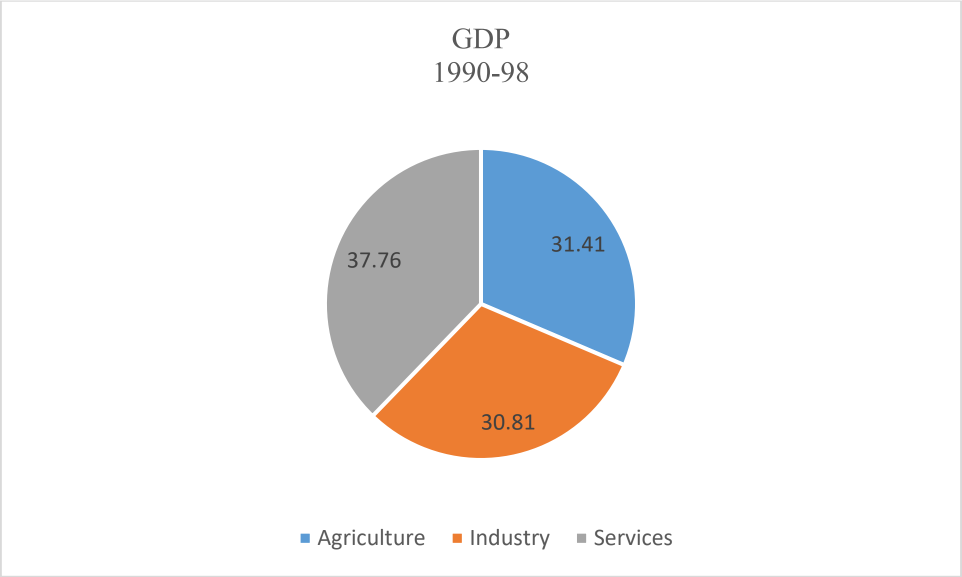


Figure 3

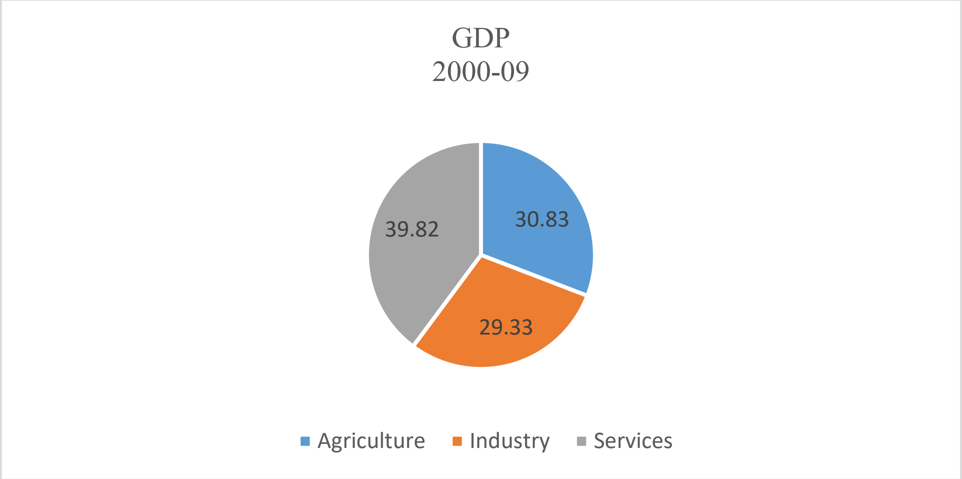


Figure 4

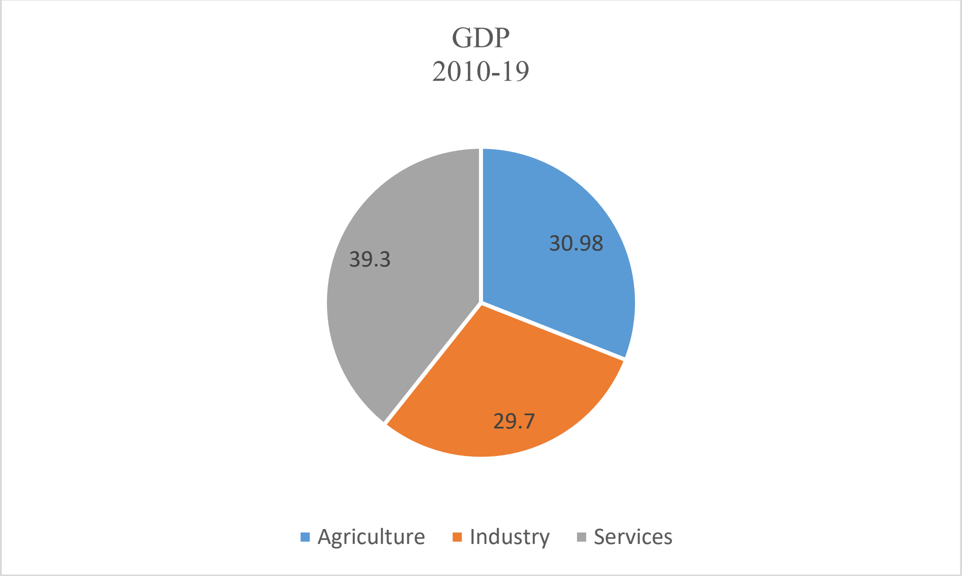


Figure 5

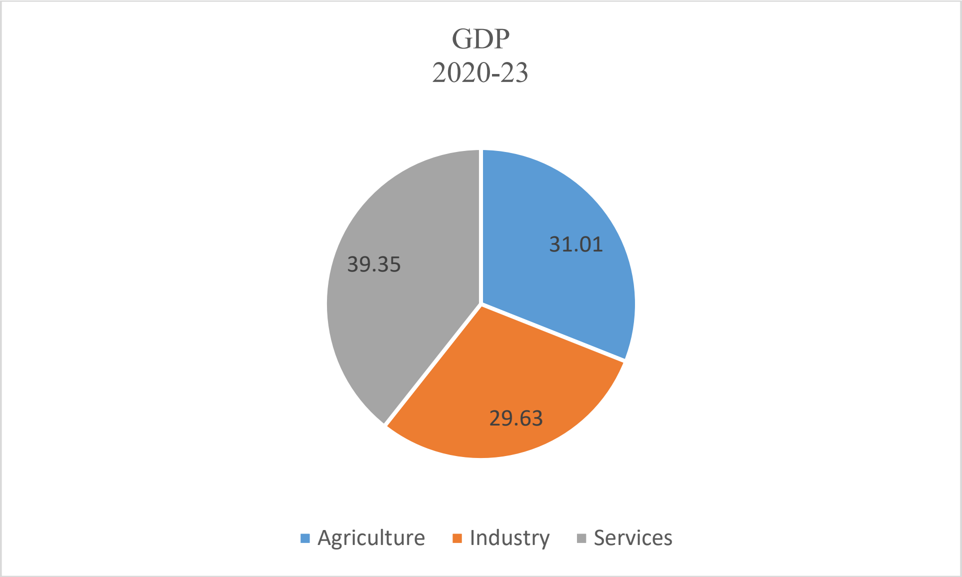


Figure 6

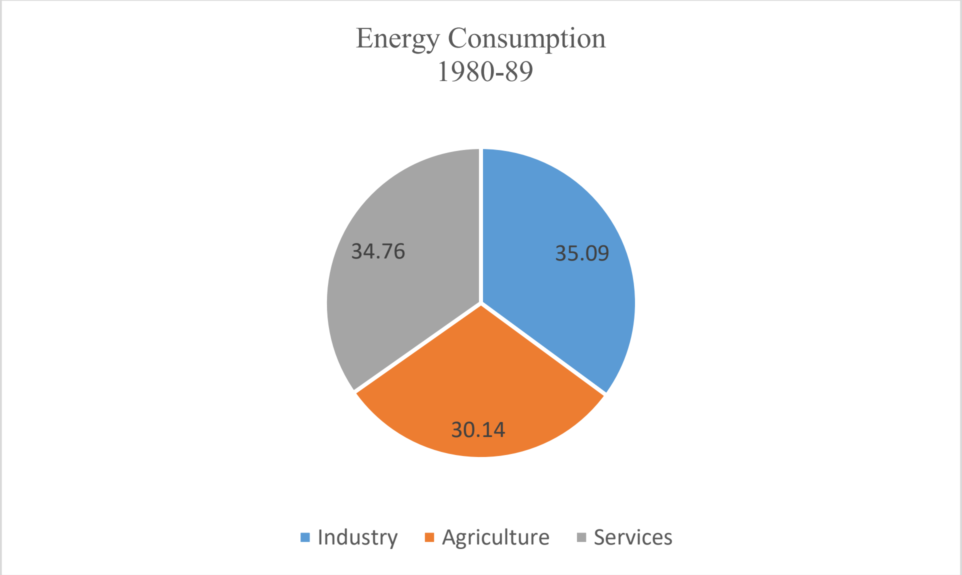


Figure 7

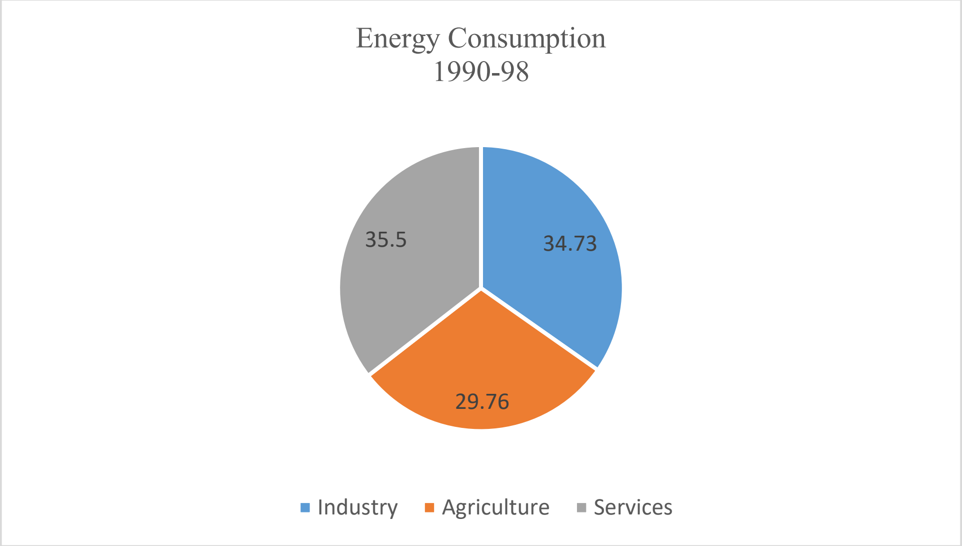


Figure 8

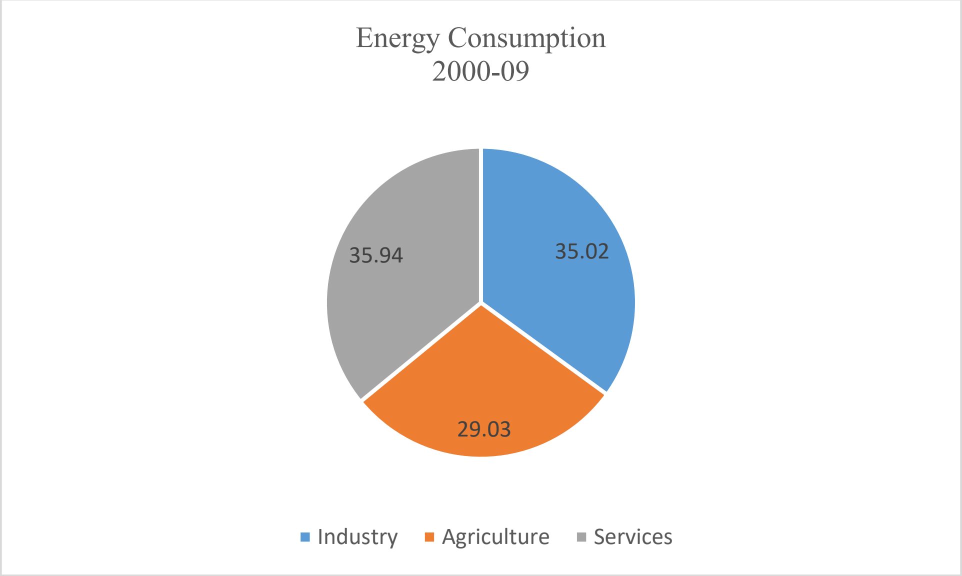


Figure 9

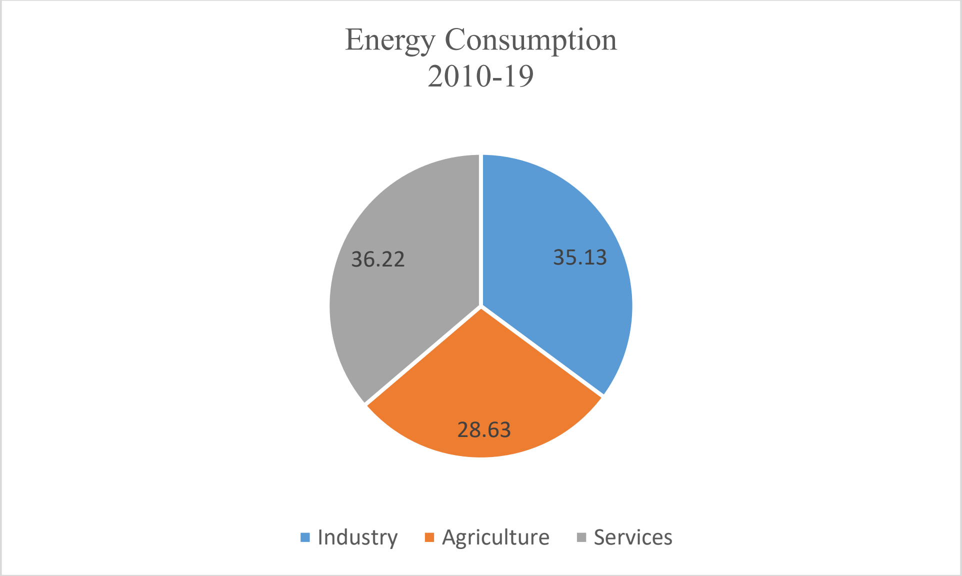
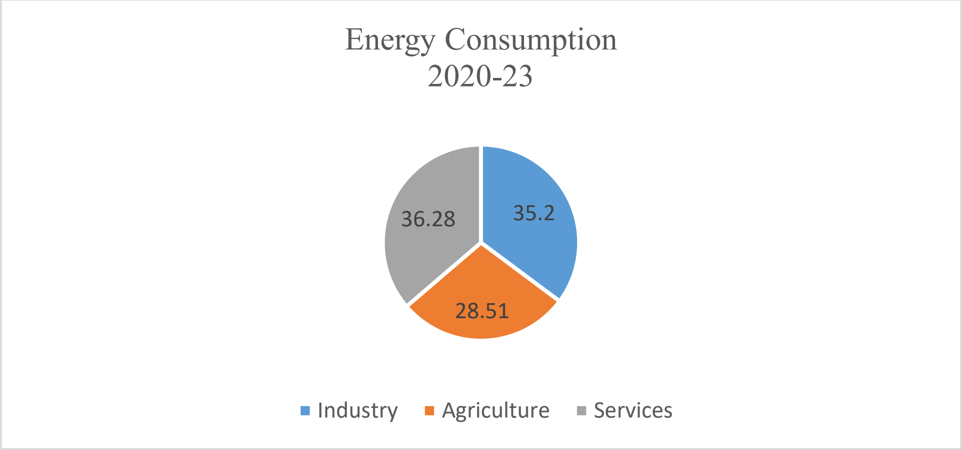


Figure 10



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