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ENERGY CONSUMPTION AND INDUSTRIAL GROWTH IN PAKISTAN

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Abstract

Industrial growth plays a vital role in the economic development of Pakistan by contributing to employment generation, productivity enhancement, and national income. This study examines the impact of energy consumption on industrial growth in Pakistan using annual time-series data from 1976 to 2024. Industrial growth is measured through industrial value added, while energy consumption is considered the primary explanatory variable. In addition, trade openness, inflation, and labour force participation are included as control variables to capture the broader macroeconomic environment affecting industrial performance. The study employs the Autoregressive Distributed Lag (ARDL) approach to investigate both short-run and long-run relationships among the variables. The empirical findings confirm the existence of a long-run cointegrating relationship between energy consumption and industrial growth. The results indicate that energy consumption, trade openness, and labour force participation positively contribute to industrial development, whereas inflation exerts an adverse effect on industrial performance. The study highlights the importance of ensuring a reliable energy supply, maintaining macroeconomic stability, and promoting trade and workforce development to achieve sustainable industrial growth in Pakistan. The findings provide valuable insights for policymakers in designing effective energy and industrial policies.

Keywords: Energy Consumption, Industrial Growth, ARDL Model, Trade Openness, Inflation, Pakistan

1. Introduction

1.1 Background and Context

The industrial sector's performance has a big effect on how well a country's economy expands. In emerging economies such as Pakistan, the industrial sector serves as a foundation for growth by generating employment opportunities, enhancing productivity, and making substantial contributions to exports and national income. A widely recognized indicator of how well an industry is doing is to look at the percentage of GDP that industrial value added makes up. This shows how much industrial activity adds to the economy as a whole. A higher proportion of industrial value added signifies that the industrial base is more developed and productive.

Energy has become an important factor in industrial growth in the last few decades. Electricity, natural gas, oil, and coal are just a few exemplifications of the types of energy that modern industries need to keep their machines running, their production lines running, and their efficiency up. Industries can't work right if they don't have a dependable and cheap source of energy. The issue of energy has remained a significant challenge in Pakistan. Pakistan's industrial sector is very vulnerable to changes in the price of oil around the

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world because it relies on imported oil for about 80–85% of its needs. The country has had a lot of problems with energy shortages, power outages, and rising energy costs, all of which have hurt industrial growth and productivity. The problems get worse when oil prices go up and there is more tension in the Middle East and other parts of the world. These problems get worse when oil prices change a lot around the world and there are political tensions, especially in the Middle East. This makes energy prices go up and makes things less certain. These problems have not only cut production, but they have also made investors less likely to put money into the industrial sector in their own countries and abroad (Rahman & Asif, 2026). When major oil supply routes like the Strait of Hormuz are blocked, oil prices can go up a lot, which can cause inflation to go up and industrial performance to go down.

A widely used measure of how much energy an economy uses is to look at how much energy each person uses. It shows how much energy people and businesses have and use. More energy use per person is usually linked to more industrial activity, better technology, and higher living standards. The link between energy use and industrial growth is not always apparent; further energy use can help industries grow, but using energy inefficiently or depending on expensive energy sources can hurt production costs and competitiveness.

In conjunction with energy consumption, a number of macroeconomic factors also have a big effect on industrial growth. One of these things is the inflation rate, which shows how prices has raises over time. When inflation is high, it can make the cost of raw materials, wages, and other things needed for industrial production go up. This can lower profit margins and make investors less sure about their investments, which can deceleration industrial growth. On the other hand, stable and moderate inflation can make the economy more predictable, which can foster industrial expansion.

Trade openness constitutes another key determinant. It measures how much a country is involved in international trade. Trade openness can support industries grow by enabling them to reach larger markets, better technologies, and money from other countries. It lets businesses in the country grow their output and become more efficient by contending with each other. However, too much openness without the right protection or support can make local businesses face tough competition from abroad, which could hurt less developed areas.

This study seeks to analyse the relationship between energy consumption and industrial growth in Pakistan, while also accounting for the influences of inflation, trade openness, gross capital formation, and the labour force. The study aims to offer a thorough comprehension of the factors influencing industrial value added in Pakistan by examining these variables inclusively. The results of this study will assist policymakers in formulating strategies to enhance energy management, stimulate investment, and foster sustainable industrial growth in the nation.

Over the last few decades, a lot of economic writing has talked about how energy use and economic growth are related. Numerous researchers regard energy as a fundamental input in the production process, akin to labour and capital. Industrial activities can't run smoothly without enough energy, which has a direct impact on the economy. Consequently, numerous studies have examined the impact of energy consumption on industrial and overall economic growth, particularly in developing nations.

1.2 Research Gap

Although many studies have examined the relationship between energy consumption and economic growth, limited research has specifically focused on its impact on industrial growth in Pakistan. Most previous studies have concentrated on overall economic growth, energy shortages, or the energy sector, while giving less attention to industrial value added as a measure of industrial performance. In addition, important factors such as trade openness, inflation, and labour force have often been overlooked.

This study addresses this gap by investigating the effect of energy consumption on industrial growth in Pakistan using recent time-series data. The findings will provide useful insights for policymakers in developing effective energy and industrial policies to support industrial development and sustainable economic growth.

1.3 Problem Statement

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Pakistan's industrial sector is an important contributor to economic growth, employment, and exports. However, industrial performance has been adversely affected by persistent energy-related challenges, including electricity shortages, rising fuel and gas prices, and an unstable energy supply. Since industries rely heavily on energy for production and transportation, these problems increase production costs, reduce efficiency, and limit industrial expansion.

In recent years, Pakistan has become increasingly vulnerable to fluctuations in international oil prices due to its heavy dependence on imported energy resources. Rising petroleum and gas prices have increased manufacturing and operating costs, placing financial pressure on industries and reducing their competitiveness in domestic and international markets. Moreover, the country's ongoing energy crisis and circular debt issues continue to create uncertainty in energy availability, affecting industrial productivity and sustainable growth (Asif et al., 2025).

Given these challenges, it is important to examine how energy consumption influences industrial growth in Pakistan. Understanding this relationship can help policymakers develop effective energy strategies to support industrial development and economic stability.

1.4 Research Question

To what degree/extent does energy consumption in interaction with key macroeconomic factors affects industrial growth in Pakistan?

1.5 Objective of the Study

The primary objective of this research is to analyse the effect of energy consumption on industrial growth of Pakistan. The specific objectives of this study are:

- To study the association between energy consumption and industrial growth in Pakistan.
- To analyse the effects of trade openness, inflation, and labour force on industrial growth in Pakistan and suggest policy recommendations.

1.6 Scope of the Study

This study examines the impact of energy consumption on industrial growth in Pakistan. Industrial growth is measured through industrial value added, while energy consumption is the main explanatory variable. The study also incorporates other important macroeconomic factors, including trade openness, inflation and labour force to provide a broader understanding of industrial performance.

The research is based on Pakistan's national-level time series data covering a period of 49 years. It focuses on the industrial sector, including manufacturing and other energy-intensive industries. The study aims to analyse the long-run relationship between energy consumption and industrial growth and to assess how other economic factors influence industrial development.

This study gives a complete picture of the thing that affect industrial growth in Pakistan by looking at these variables and how they work together it shows how important energy is to economic growth.

2. Literature Review

The connection between energy use and economic growth has been studied a lot in the real world especially in developing countries. Energy is widely acknowledged as a vital input in the production process serving not only as a supportive element but also as a catalyst for industrialization. Several studies have shown that there is a long-term balance between energy use and economic growth in Pakistan. This means that having enough energy is important for keeping industrial output going.

Different types of energy use like electricity, natural gas and oil, have different effects on how well industries do according to real-world data. Industrial electricity use in particular, has been shown to be a big factor in increasing production efficiency and output. Gas use is also very important for supporting manufacturing, especially in sectors that use a lot of energy. However, relying on non-renewable energy sources has also led to higher production costs and environmental problems, which shows how important it is to have a balanced mix of energy sources.

Along with energy use, macroeconomic variables have been widely used in growth models to explain why industrial performance changes. Inflation is usually bad for industrial growth because it makes inputs more expensive and makes investors unsure about what will happen. The literature has shown mixed results

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for trade openness. It can help businesses be more efficient and give them access to global markets, but too much exposure to international competition can slow the growth of domestic industries. Investment in physical infrastructure and technological advancement is important for industrial growth, and gross capital formation is always seen as a good thing for this. The labour force also helps industry be more productive, but how well it does this depends on skill levels and the development of human capital.

Recent research has increasingly concentrated on the influence of external shocks and global energy dynamics in determining economic outcomes. The Pakistan Institute of Development Economics's policy-oriented research shows that Pakistan's economy is vulnerable to changes in oil prices around the world because it relies so heavily on imported oil. Changes in the price of oil around the world, which are often caused by political tensions in the Middle East, have a big effect on the country's import bill, inflation rate, and overall industrial costs. These kinds of outside shocks can stop businesses from working by raising energy costs and lowering production efficiency (Mushtaq et al., 2026).

There are also risks to Pakistan's energy security because of uncertainties about the global energy supply, especially when it comes to strategic transit routes like the Strait of Hormuz. When these routes are blocked, oil prices can suddenly go up, which makes inflation worse and slows down industrial growth. These results imply that external energy market conditions should be evaluated in conjunction with domestic factors when assessing industrial performance.

There is a lot of research on energy use and economic growth, but not many studies have looked at how energy use and macroeconomic factors affect industrial value added in Pakistan. Most current studies concentrate on either overall economic growth or specific variables, failing to incorporate essential factors like inflation, trade openness, capital formation, and labour force into a cohesive framework. This study endeavours to fill this void by offering a thorough examination of the interplay between energy consumption and macroeconomic variables in influencing industrial growth in Pakistan.

2.1 Theoretical Background

The relationship between energy consumption and industrial growth has been explained by different economic theories and growth models. In economics, energy is considered one of the essential inputs of production because industrial activities cannot function properly without a stable supply of electricity, gas, oil, and other energy resources. Industries depend on energy to operate machinery, maintain production processes, and improve efficiency. Therefore, the availability and consumption of energy play an important role in determining industrial performance and economic development.

One of the most important theories related to this study is Classical Production Theory. According to this theory, production is a function of various factors such as labour, capital and natural resources. Modern economists also treat energy as an important productive input. Industries require a continuous supply of energy to increase output and productivity. If energy resources are insufficient or costly, industrial production may decline and industrial growth may be slower.

Also, the study is based on the Cobb-Douglas Production Function theoretically. According to model, output is produced by the combination of labour and capital inputs. However, in modern economies energy is often considered as an additional factor of production as it directly affects the efficiency and productivity of industries. The rise in energy consumption generally facilitates industrial production through manufacturing activities, transportation, and technological operations.

Another important theory related to this research is the Energy-Led Growth Hypothesis. According to the theory, energy consumption drives industrial and economic growth. This hypothesis holds that the availability of higher energy supplies raises the capacity of industrial production, stimulates investment, and supports economic growth. Better energy infrastructure correlates with more industrial productivity and sustainable economic growth.

The study also examines the role of important macroeconomic variables like trade openness, inflation and participation rate of labour force. International trade provides industries with larger markets, modern technologies and opportunities for foreign investment so that trade openness is associated with industrial

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growth. Similarly, the labour force participation leads to industrial productivity as a consequence of availability of human resources and skilled workers.

2.2 Review of Relevant Literature

Umair et al. (2024) analyse the influence of labour force, physical capital, and energy consumption, encompassing electricity, oil, and gas, on agricultural and industrial output in Pakistan, utilising annual data from 1990 to 2022. The research utilises the Autoregressive Distributed Lag (ARDL) model in conjunction with DOLS and FMOLS methodologies to guarantee reliable outcomes. The results show that in both the short and long term, the amount of physical capital, labour, and energy used in agriculture and industry has a big effect on output. Also, the combined effect of using electricity and oil is stronger than the effects of each one on its own. The study emphasises the significance of energy in industrial performance, incorporating additional variables, whereas the current study concentrates solely on the direct correlation between energy consumption and industrial growth.

Abbasi et al. (2021) analyse the effects of energy consumption, industrial expansion, urbanisation, and carbon emissions on economic growth in Pakistan from 1972 to 2018. The research employs a dynamic ARDL simulation methodology in conjunction with a frequency-domain causality test to examine both short-term and long-term relationships among the variables. The findings indicate that electricity consumption and industrial value-added substantially contribute to economic growth in both the short and long term, underscoring the significance of energy availability and industrial activity for economic performance. The research additionally identifies beneficial impacts of urbanisation and CO_2 emissions in the short term. This research concentrates on overall economic growth rather than a detailed examination of industrial growth, thereby allowing for additional sector-specific studies such as the current one.

Khan et al. (2021) examine the dynamic interplay among industrialisation, energy consumption, carbon emissions, urbanisation, transportation, and agricultural product exports in Pakistan through the Autoregressive Distributed Lag (ARDL) methodology and Granger causality tests. The findings demonstrate that energy consumption and industrialisation positively impact agricultural exports in both the short and long term, whereas urbanisation, transportation, and carbon emissions exert a negative influence on exports over the long term. The study stresses how important it is for economic stability to use energy and manage the environment in a way that is good for the long term. But its main focus is on agricultural exports, not industrial growth, which makes it only somewhat relevant to the current research.

Chandio et al. (2019) examine the dynamic interplay between industrial energy consumption and economic growth in Pakistan. The research analyses the effects of industrial consumption of electricity, gas, oil, and renewable energy through cointegration and vector error correction (VECM) methodologies. The findings validate a long-term correlation between industrial energy consumption and economic growth. In the short and long term, using electricity and gas in factories has a positive and big effect on economic growth. In the long run, though, using oil in industry hurts economic growth, while in the short run, it helps. The research identifies both bidirectional and unidirectional causal relationships among variables. This study is very important because it directly shows how energy use in industry affects the economy in Pakistan (Hussain & Asif, 2026).

Rauf et al. (2015) Give an overview of Pakistan's energy situation and development, focusing on how energy is a major factor in economic growth and development. The study shows that Pakistan has a lot of natural energy resources, but it still relies heavily on foreign energy supplies and is running out of energy. It looks at how the energy sector has changed over time, how it is set up, how much power it can generate, and what resources it has, such as coal, oil, gas, nuclear, and renewable sources like wind, solar, hydel, and biogas. The paper talks about the energy crisis, what caused it, and how it affected the economy. It also suggests ways to fix the problem, like making energy policies better, putting more money into renewable energy, and closing the gap between supply and demand. further stresses renewable energy as a long-term solution to Pakistan's on energy crisis.

Afia Malik (2012) looks at the power crisis in Pakistan from the points of view of governance and policy. According to the study, Pakistan went from having too much electricity in the early 2000s to having

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too little after 2006–07. This was because the gap between electricity demand and supply grew. The shortage got so bad that there was a lot of load shedding in both cities and the countryside. The study finds that the crisis is mostly caused by a rapid rise in electricity demand, not enough generation capacity, high transmission and distribution losses, a seasonal drop in hydropower, running out of natural gas reserves, and a heavy reliance on imported fuel oil. Circular debt made it even harder to make electricity. The study finds that Pakistan's ongoing electricity crisis and overall energy instability are mostly caused by weak governance, bad planning, and bad energy management.

Shahbaz et al. (2012) analyse the correlation between energy consumption and economic growth in Pakistan, utilising data from 1972 to 2011. The research utilises the Cobb–Douglas production function in conjunction with ARDL bounds testing and structural break cointegration methods to examine long-term relationships. The results show that both renewable and non-renewable energy use have a big effect on economic growth. Furthermore, capital and labour are recognised as significant factors influencing economic performance. The study utilises VECM Granger causality analysis, demonstrating a reciprocal relationship between energy consumption and economic growth, signifying that both variables exert mutual influence. The results indicate that energy consumption is a significant driver of economic growth in Pakistan and should be regarded as a critical element in policy formulation.

Abdoli et al. (2015) investigate the correlation between electricity consumption and economic growth in OPEC nations, utilising annual data from 1980 to 2011. The research employs panel cointegration and error correction models, in conjunction with fully modified ordinary least squares estimation, to examine both long-term and short-term relationships. The results validate a long-term correlation among electricity consumption, economic growth, and trade activities. In the short term, electricity consumption plays a big role in economic growth and backs up the feedback hypothesis, which means that the two variables are related in both directions. The findings indicate that enhancements in electricity consumption efficiency do not adversely impact long-term economic growth. The study offers substantial international evidence regarding the connection between energy and growth; however, its concentration on OPEC nations restricts its direct applicability to Pakistan (Mumtaz et al., 2023).

Safiya Aftab (2014) looks at Pakistan's energy crisis and says that it is a major problem for the country's economy. says that the crisis started when the energy mix changed from hydropower to imported furnace oil, which made the cost of making electricity go up a lot. High losses in transmission and distribution made things even worse, causing higher tariffs and financial losses in the power sector. It shows how circular debt can happen when payments are late, which stops fuel from getting to power plants and makes them less efficient, which means that they don't use all of their generation capacity. It also says that big government subsidies put even more strain on the national budget. The study talks about policy changes that the IMF has agreed to, such as changing tariffs and better managing fuel, that are meant to make the energy sector in Pakistan more stable and less wasteful (Pasha et al., 2019).

Raza and Lin (2024) Utilise a trans-log production function to analyse energy substitution opportunities and technological advancements within Pakistan's industrial sector. The study examines the energy-intensive characteristics of industry and its growing impact on overall energy consumption and emissions. Ridge regression is a method for dealing with multicollinearity between variables. The results show that all inputs have increasing returns to scale and that energy and non-energy inputs can easily be switched out for each other, especially capital, labour, oil, gas, coal, and electricity. The results show that capital and labour can replace energy inputs, which is good for long-term industrial growth. Technological advancement differs among energy combinations, indicating variations in efficiency among energy sources. The study finds that Pakistan needs to make its industries more sustainable by improving energy efficiency, using more capital and labour, and making technological progress.

2.3 Conceptual Framework

The conceptual framework of this study explains the relationship between energy consumption and industrial growth in Pakistan. Industrial growth is taken as the dependent variable because it represents the

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overall performance of the industrial sector. Energy consumption is considered the main independent variable since industrial activities largely depend upon energy resources for production and operational processes.

The study also includes trade openness and inflation as explanatory variables because these macroeconomic factors influence industrial productivity and economic performance. Trade openness helps industries access international markets, foreign investment, and advanced technologies, while inflation affects industrial costs, production efficiency, and purchasing power. In addition, labour force participation is included as a control variable because human resources play an important role in industrial production and economic activities. The conceptual framework assumes that changes in energy consumption and other macroeconomic variables directly or indirectly influence industrial growth in Pakistan.

It was pointed out in the literature that energy is very important for industrial development as industries depend on electricity, fuel and other energy sources for their production activities. Previous studies have found mixed results regarding the link between energy consumption and industrial expansion and this calls for more research in the setting of Pakistan.

Furthermore, the conceptual framework of the study explained the relationship between dependent, independent, and control variables. Overall, this chapter provided the theoretical foundation and research support for examining the impact of energy consumption on industrial growth in Pakistan.

3. Data and Methodology

This paper explains the methods and procedures used to conduct the research on energy consumption and industrial growth in Pakistan. It discusses the problem statement, objectives of the study, research design, sources of data, variables used in the analysis, and the econometric model applied in the study. The purpose of this chapter is to provide a clear understanding of how the research has been carried out in a systematic and reliable manner.

A proper research methodology is important because it helps maintain direction throughout the study and ensures that the findings are based on factual evidence rather than personal opinions. It also helps reduce bias, improves the accuracy of the analysis, and makes the research easier to understand for other researchers and policymakers. Since this study uses numerical data and statistical analysis, it follows a quantitative approach. The study is explanatory in nature because it aims to explain how energy consumption affects industrial growth in Pakistan over time.

3.1 Research Design and Data

3.1.1 Research Design. The study uses a quantitative and explanatory research design using annual time series data for Pakistan. The quantitative research is appropriate as the study is based on the measurable economic variables such as energy consumption, inflation, trade openness, and industrial growth. The explanatory design will help to analyse the relationship between these variables and know how they influence industrial performance.

The research is centred on Pakistan in particular because the country has been grappling with severe energy issues over the years such as electricity shortages, rising fuel prices and industrial inefficiencies. These problems have had an impact on industrial productivity and economic growth. Therefore, this study attempts to empirically explore the impact of energy consumption on industrial growth in Pakistan.

3.1.2 Targeted Population. This study is based on annual macroeconomic data of Pakistan covering the period from 1976 to 2024. The target population includes key economic indicators such as industrial growth, energy consumption, trade openness, inflation rate, and labour force participation.

Instead of focusing on individuals or firms, this research uses yearly observations of these macroeconomic variables. These indicators collectively reflect the overall industrial and economic performance of Pakistan over time.

The main purpose of selecting this population is to examine the long-term relationship between energy consumption and industrial growth, along with other important economic factors that influence industrial performance in Pakistan.

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3.1.3 Nature and Source of Data. The study is based on secondary data collected from the World Development Indicators (WDI) database published by the World Bank. WDI is an internationally recognized and reliable source of economic data commonly used in academic research.

Annual data for all variables has been collected for approximately 49 years, depending on the availability of observations. The use of long-term data helps examine both short-run and long-run relationships among the variables.

The following variables are included in the study: Industrial growth (IND), Energy Consumption (EC), Trade Openness (TO), Inflation (INF), and Labour Force (LF).

All data has been obtained from the World Development Indicators (WDI) database to ensure consistency, authenticity, and reliability in the analysis.

3.2 Measurement Variables

3.2.1 Dependent Variable ($\hat{Y}$). A dependent variable is the outcome that is influenced by other factors in a cause and effect relationship. In this study the dependent variable is industrial growth.

Industrial Growth (IND): Industrial growth is used as the dependent variable in the study. It is measured by industrial value added as a percentage of GDP. This variable represents the contribution and performance of the industrial sector in Pakistan's economy.

3.2.2 Independent Variables (X). Independent variables are the main factors expected to influence the dependent variable. In this research, three independent variables are considered.

Energy Consumption (EC): The main independent variable of the study is energy consumption. It is measured by energy use per capita (kg of oil eq). Energy is a vital input for the industrial sector, as industries rely heavily on electricity, fuel, gas and other energy resources for their manufacturing and operational activities.

Trade Openness (TO): Trade openness is measured as the sum of exports and imports as percent of GDP. It shows how much Pakistan is linked with international trade and global markets. Trade openness can influence industrial growth through foreign investment, transfer of technology and expansion of market.

Inflation (INF): Inflation is the percentage increase in the general price level over a year. High inflation might raise production costs, decrease purchasing power and cause uncertainty for industries, which can have a negative impact on industrial growth.

3.2.3 Control Variable. Control variables are factors that remain constant in order to reduce bias and improve the reliability of results. In this study one control variable is included.

Labour Force: Labour force is included as a control variable in the study. It represents the economically active population involved in production activities. The inclusion of labour force helps control the effect of workforce participation on industrial growth, making the results more accurate and reliable.

3.3 Estimation Method and Econometric Model

3.3.1 Estimation Method. This study uses the Autoregressive Distributed Lag (ARDL) approach to investigate the nexus between energy consumption and industrial growth in Pakistan. The ARDL approach is widely used in economic research because it facilitates the estimation of the short run and long run relationships between variables.

The ARDL model is appropriate for this study since some of the variables are stationary at level and others are stationary at first difference. The mixed order of integration of the variables makes the ARDL approach to produce reliable and efficient results. The method also has the advantage of performing well with small sample size and annual time series data.

Before estimating the model, unit root tests are applied to check whether the variables are stationary or non-stationary. After confirming the order of integration, the ARDL Bound Test is conducted to determine whether a long-run relationship exists among industrial growth, energy consumption, trade openness, inflation, and labour force.

In addition, several diagnostic tests are performed to examine the reliability of the estimated model. These tests include serial correlation, heteroskedasticity, normality, and stability tests. The stability of the model is further checked through CUSUM and CUSUM of Squares tests.

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The entire analysis is carried out using EViews software.

3.3.2 Econometric Model Specification. The econometric model explains the relationship between industrial growth and the explanatory variables included in the study. Industrial growth is taken as the dependent variable, while energy consumption, trade openness, inflation, and labour force are used as explanatory variables.

The functional form of the model is:

IND = f(EC, TO, INF, LF)

Where:

IND = Industrial Growth
EC = Energy Consumption
TO = Trade Openness
INF = Inflation Rate
LF = Labour Force

The econometric form of the model is written as:

$$IND_t = \beta_0 + \beta_1 EC_t + \beta_2 TO_t + \beta_3 INF_t + \beta_4 LF_t + \varepsilon_t$$

$$INDt = \beta_0 + \sum_{i=1}^{p} \beta_1 INDt\text{-}i + \sum_{i=0}^{\varphi 1} \beta_2 ECt\text{-}i + \sum_{i=0}^{\varphi 2} \beta_3 TOt\text{-}i + \sum_{i=0}^{\varphi 3} \beta_4 INFt\text{-}i + \sum_{i=0}^{\varphi 4} \beta_5 LFt\text{-}i + \varepsilon t$$

Variable Representation: In the above regression model, **IND** represents industrial growth, which is the dependent variable. β_0 is the intercept term showing the baseline level of industrial growth when all explanatory variables are zero.

β_1, β_2, β_3, and β_4 are the coefficients of the independent variables. Specifically, **β_1 (energy consumption)** measures the effect of energy usage on industrial growth. **β_2, β_3, and β_4** show the impact of trade openness, inflation, and labour force respectively on industrial growth.

ε_t is the error term, which captures all other factors not included in the model that may affect industrial growth.

The inclusion of these variables helps in better understanding how energy availability and macroeconomic conditions collectively influence industrial performance in Pakistan.

This part explained the research methodology used in the study to analyse the impact of energy consumption on industrial growth in Pakistan. It discussed the research design, data source, variable measurements, and statistical techniques used for the analysis.

The study used annual time series data for the period 1976 to 2024 collected from the World Development Indicators (WDI). Industrial growth was taken as the dependent variable, while energy consumption, trade openness, inflation, and labour force were included as explanatory variables.

The ARDL estimation technique was selected because it is appropriate for variables integrated at mixed levels and helps estimate both short-run and long-run relationships. Different diagnostic and stability tests were also discussed to ensure the reliability and validity of the model.

Overall, this chapter provided the methodological framework for conducting the empirical analysis presented in the next chapter.

4. Results and Analysis

The empirical results and economic analysis of the relationship between energy consumption and industrial growth in Pakistan using annual time-series data spanning from 1976 to 2024. To ensure a robust empirical investigation, the analytical framework is structured into multiple stages. First, descriptive statistics are analysed to understand the historical behaviour, central tendency, and distributional properties of the variables under study. Second, an unconditional correlation analysis is performed to evaluate preliminary co-movements and screen for potential multicollinearity issues. Third, unit root testing is utilized to determine the integration order of the series. Given the mixed order of integration (I(0) and I(1)), the Autoregressive Distributed Lag (ARDL) Bounds testing approach to cointegration is utilized to capture both short-run dynamics and long-run equilibrium relationships. Finally, standard econometric diagnostic tests and stability evaluations (CUSUM and CUSUM of Squares) are conducted to ensure the statistical reliability and policy relevance of the estimated parameters.

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4.1 Descriptive Analysis

4.1.1 Descriptive Statistics. Before proceeding to serious econometric modelling, the basic statistical properties of the operational variables, Industrial Growth (IND), Energy Consumption (EC), Inflation Rate (INF), Labour Force (LF), and Trade Openness (TO) need to be investigated.

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Table 1

Descriptive Statistics

Statistic	EC	IND	INF	LF	TO
Mean	2.606984	20.46585	8.962392	50.00347	31.10548
Median	2.610656	20.71869	8.267047	50.08400	32.31996
Maximum	2.684368	22.93092	30.76813	52.73000	38.49932
Minimum	2.558057	17.15889	2.529328	47.40000	21.45996
Std. Dev.	0.036707	1.512454	5.029095	1.411652	4.263530
Skewness	0.099866	-0.575696	1.941687	-0.048617	-0.346055
Kurtosis	1.781180	2.605874	8.899167	2.206731	2.268959
Jarque-Bera	3.114388	3.023783	101.8399	1.304076	2.069101
Probability	0.210727	0.220493	0.000000	0.520983	0.355386
Sum	127.7422	1002.827	439.1572	2450.170	1524.169
Sum Sq. Dev.	0.064675	109.8008	1214.006	95.65256	872.5290
Observations	49	49	49	49	49

Note. EC = Energy Consumption, IND = Industrial Growth, INF = Inflation Rate, LF = Labour Force, TO = Trade Openness.

The descriptive statistics presented in Table 1 explain the overall behaviour and characteristics of the variables used in the study during the period 1976–2024. The statistics include mean, maximum value, minimum value, standard deviation, skewness, kurtosis, and Jarque-Bera probability values.

The average value of Industrial Growth (IND) is 20.47 percent, which indicates that the industrial sector contributed approximately 20 percent to Pakistan's GDP during the study period. The standard deviation is relatively low, showing that industrial growth remained fairly stable over time with limited fluctuations.

Energy Consumption (EC) has an average value of 2.61, while its low standard deviation indicates that energy usage remained comparatively stable throughout the period. This suggests that Pakistan's energy consumption followed a consistent trend over the years despite economic changes and fluctuations in industrial activities.

Inflation (INF) recorded an average value of 8.96 percent. The maximum and minimum values show that inflation experienced significant variations during different periods in Pakistan's economy. The high standard deviation further indicates instability in prices, reflecting the presence of economic shocks, rising production costs, and fluctuations in the general price level over time.

The Labour Force (LF) variable shows an average value of 50 percent, which means that a large proportion of the population remained economically active during the study period. The relatively small variation in labour force participation indicates consistency in workforce involvement in economic activities.

Trade Openness (TO) has an average value of 31.11 percent, suggesting that Pakistan maintained a moderate level of involvement in international trade. The standard deviation shows that trade openness experienced some fluctuations over time due to changes in trade policies, imports, exports, and global economic conditions.

The skewness values indicate the nature of the data distribution for each variable. Negative skewness values for industrial growth, labour force, and trade openness show that these variables are slightly left-skewed, while energy consumption and inflation are positively skewed. Inflation, in particular, shows a relatively high positive skewness, indicating the occurrence of frequent increases in prices during certain periods.

Kurtosis values explain the shape of the data distribution. Most variables have kurtosis values close to normal distribution, while inflation shows a relatively high kurtosis value, suggesting the presence of extreme values and economic shocks during the study period.

Finally, the Jarque-Bera test is used to examine whether the variables are normally distributed. The probability values of industrial growth, energy consumption, labour force, and trade openness are greater than 0.05, indicating that these variables follow normal distribution. However, inflation does not appear to be

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normally distributed because its probability value is less than 0.05. Overall, the descriptive statistics suggest that the data is suitable for further econometric analysis.

4.2 Unit Root Test

Table 2

Unit Root/ADF Testing Results

Variables	ADF t-Statistic	Probability	Integration Order
Inflation (INF)	-5.538913	0.0002	I(0)
Labour Force (LF)	-6.711266	0.0000	I(1)
Gross Capital Formation (GFCF)	-6.269744	0.0000	I(1)
Exports (% of GDP) (EXP_GDP)	-6.802750	0.0000	I(1)
Imports (% of GDP) (IMP_GDP)	-7.018226	0.0000	I(1)
Industrial Value Added (IND_VA)	-6.949882	0.0000	I(1)

Before estimating the ARDL model, it is necessary to examine the stationarity properties of the variables. The Augmented Dickey-Fuller (ADF) unit root test was employed to determine whether the variables contain a unit root or are stationary over time.

The results indicate that Industrial Growth (IND), Energy Consumption (EC), Gross Capital Formation (GCF), Trade Openness (TO), and Labour Force (LF) are non-stationary at level under both intercept-only and intercept-with-trend specifications. However, all of these variables become stationary after taking the first difference. Therefore, these variables are integrated of order one, I(1).

In contrast, Inflation (INF) was found to be stationary at level under both specifications, indicating that it is integrated of order zero, I(0). Since inflation does not require differencing to achieve stationarity, it can be directly included in the model estimation.

Overall, the unit root results reveal a mixed order of integration among the variables, where some variables are integrated at I(0) while others are integrated at I(1). This combination of integration orders justifies the use of the Autoregressive Distributed Lag (ARDL) approach, as the ARDL model is appropriate when variables are stationary at level and first difference, but none are integrated at second difference I(2).

The findings confirm that the data satisfy the basic requirement for ARDL estimation and allow the study to proceed with cointegration analysis and long-run relationship estimation.

4.3 ARDL Model Results

Table 3

ARDL Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IND(-1)	0.260685	0.088141	2.957604	0.0054
EC	0.949452	6.031064	0.157427	0.0275
TO	0.243218	0.041650	5.839556	0.0000
INF	0.022682	0.025812	0.878734	0.3852
LF	0.283382	0.216342	1.309879	0.0183
LF(-1)	-0.180524	0.281067	-0.642280	0.5247
LF(-2)	0.377866	0.274509	1.376518	0.1769
LF(-3)	-0.513602	0.230849	-2.224839	0.0323
C	6.393187	10.10176	0.632879	0.5307
R-squared: 0.855400	**Adjusted R-squared:** 0.824135	**F-statistic:** 27.35983	**Prob(F-statistic):** 0.000000	**Durbin-Watson Stat:** 1.847932

The Autoregressive Distributed Lag (ARDL) model is used to estimate both short-run and long-run relationships between industrial growth and explanatory variables.

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The coefficient of energy consumption shows the impact of energy usage on industrial growth in Pakistan. A positive coefficient indicates that higher energy consumption increases industrial growth, while a negative coefficient suggests an adverse impact.

The coefficient of trade openness explains how international trade affects industrial performance. A positive and significant coefficient indicates that trade openness contributes positively to industrial growth through increased exports, technology transfer, and foreign investment.

Inflation measures the impact of rising prices on industrial growth. A negative coefficient indicates that inflation increases production costs and creates uncertainty, which negatively affects industrial activities.

The labour force coefficient explains the contribution of workforce participation to industrial growth. A positive coefficient suggests that a larger labour force improves industrial productivity and output.

The probability values determine the significance of each variable. Variables with probability values less than 0.05 are statistically significant.

4.4 ECM Regression Estimation

Table 4

Error Correction Method Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LF)	0.283382	0.186014	1.523445	0.1361
D(LF(-1))	0.135736	0.186556	0.727587	0.4714
D(LF(-2))	0.513602	0.183613	2.797192	0.0081
CointEq(-1)*	-0.739315	0.076346	-9.683805	0.0000

Speed of Adjustment: The error correction coefficient is -0.739315 and highly significant (p = 0.0000). This confirms a long-run cointegrated relationship exists. It implies that approximately 73.9% of short-run deviations from long-run equilibrium are corrected back toward stability each period.

Short-run Lags: The second lag of the labour force difference (D(LF(-2))) holds a statistically significant short-run impact on D(IND) (p = 0.0081).

Goodness of Fit: The model explains roughly 67.7% of the variance in the dependent variable (Adjusted $R^2 = 0.6767$).

4.5 Bound Test for Cointegration

Table 5

F-Bounds Test Results

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	13.76871	10%	2.2	3.09
k	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37
Actual Sample Size	46	10%	2.372	3.32
		5%	2.823	3.872
		1%	3.845	5.15
		10%	2.402	3.345
		5%	2.85	3.905
		1%	3.892	5.173

The F-Bounds test is used to determine the presence of a long-run relationship (cointegration) among variables within an ARDL framework. The decision rules are as follows:

- If the F-statistic is higher than the upper bound I(1), the null hypothesis of no cointegration is rejected, indicating a long-run relationship exists.
- If the F-statistic falls below the lower bound I(0), the null hypothesis cannot be rejected, indicating no cointegration.

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- If the F-statistic falls between the I(0) and I(1) bounds, the result is inconclusive.

Given that computed F-statistic is 13.76871, which is substantially higher than the 1% upper bound critical value of 5.173 (for n=45) or 5.15 (for n=50). Therefore, we reject the null hypothesis of 'No levels relationship' at the 1% significance level. There is strong, statistically significant evidence of a long-run level relationship (cointegration) among the variables.

5. Diagnostic Analysis

5.1 Serial Correlation LM Test

Table 6

Breusch-Godfrey Serial Correlation LM Test

Statistic	Value	df	Probability
F-statistic	0.138208	F(2,35)	Prob. = 0.8714
Obs*R-squared	0.360442	Chi-Square(2)	Prob. = 0.8351

The Serial Correlation LM Test is used to examine whether autocorrelation exists in the residuals of the model. The null hypothesis states that there is no serial correlation. If the probability value is greater than 0.05, the null hypothesis is accepted, meaning that the residuals are free from autocorrelation.

The results show that the probability value is greater than 0.05, indicating that the model does not suffer from serial correlation problems and the estimated results are reliable.

5.2 Breusch-Pagan-Godfrey Heteroskedasticity Test

Table 7

Breusch-Pagan-Godfrey Heteroskedasticity Test

Statistic	Value	Probability
F-statistic	0.965263	Prob. F(8,37) = 0.4775
Obs*R-squared	7.942755	Prob. Chi-Square(8) = 0.4391
Scaled explained SS	4.180416	Prob. Chi-Square(8) = 0.8405

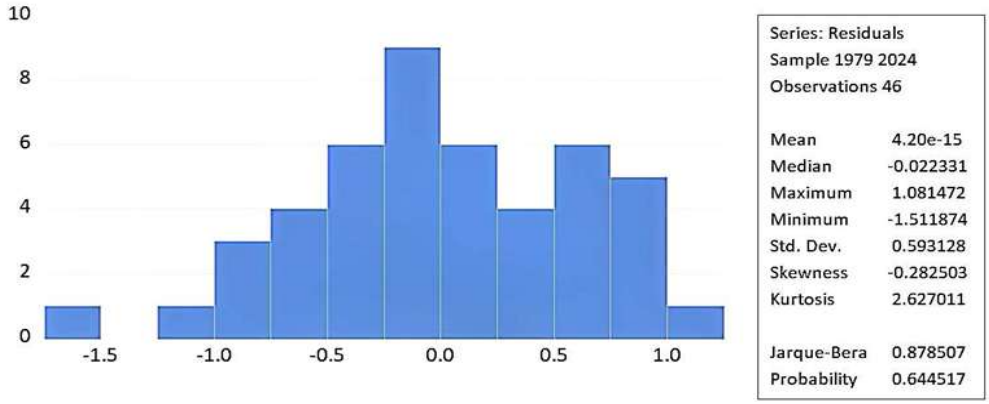
The heteroskedasticity test checks whether the variance of residuals remains constant throughout the model. The null hypothesis states that there is no heteroskedasticity problem. If the probability value exceeds 0.05, the null hypothesis is accepted.

The results indicate that the probability value is greater than 0.05, which confirms the absence of heteroskedasticity. Therefore, the variance of the residuals is constant and the regression model is considered efficient.

5.3 Normality Test

Figure 1

Histogram; Normality Test



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The normality test is conducted to determine whether the residuals of the model are normally distributed. The Jarque-Bera test is used for this purpose. If the probability value is greater than 0.05, the residuals are considered normally distributed.

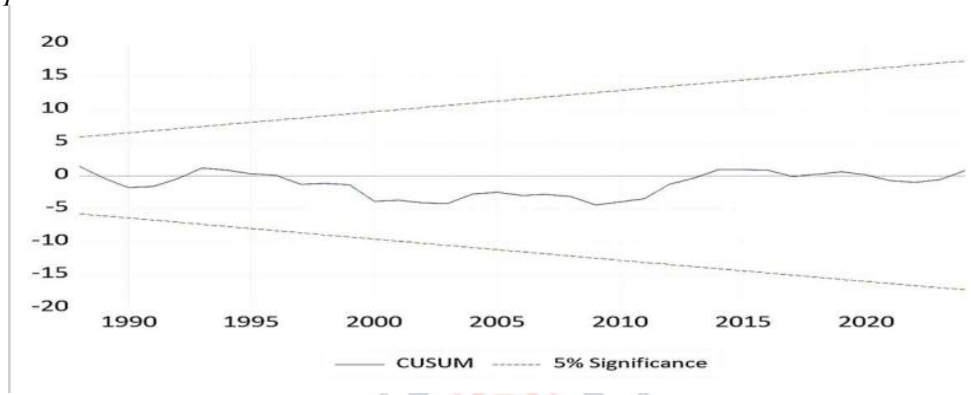
The results reveal that the residuals follow a normal distribution, which indicates that the model satisfies the normality assumption and the regression estimates are valid for statistical inference.

5.4 Stability Analysis

5.4.1 CUSUM Test

Figure 2

CUSUM Graph

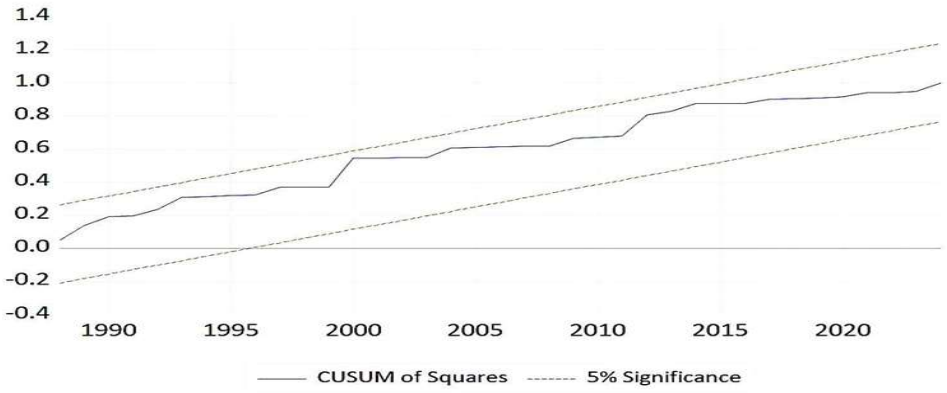


The CUSUM test is applied to examine the stability of the estimated coefficients over time. If the CUSUM line remains within the critical boundaries at the 5% significance level, the model is considered stable. The results show that the CUSUM line lies within the critical limits, indicating that the estimated model is structurally stable throughout the study period.

5.4.2 CUSUM of Squares Test

Figure 3

CUSUM of Squares Graph



The CUSUM of Squares test checks the stability of variance in the regression model. If the plotted line remains within the critical boundaries, the model is considered stable and free from structural breaks. The findings indicate that the CUSUM of Squares line stays within the critical bounds, confirming the stability and reliability of the ARDL model.

The empirical findings of the study using different econometric techniques. Descriptive statistics and correlation analysis were used to explain the behaviour and relationship among the variables. The unit root

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test confirmed that the variables were integrated at mixed order I(0) and I(1), which justified the application of the ARDL model.

The ARDL results revealed the short-run and long-run relationship between energy consumption and industrial growth in Pakistan. The Bound Test confirmed the existence of cointegration among the variables. Diagnostic tests showed that the model was free from serial correlation and heteroskedasticity, while the residuals were normally distributed. Furthermore, the CUSUM and CUSUM of Squares tests confirmed the stability of the model. Overall, the findings suggest that energy consumption and macroeconomic variables play an important role in determining industrial growth in Pakistan.

6. Conclusion and Recommendations

This chapter presents the concluding section of the study on the relationship between energy consumption and industrial growth in Pakistan. The chapter summarizes the major findings obtained from the empirical analysis and discusses their significance in the context of Pakistan's industrial development. Furthermore, it highlights the contribution of the study, policy implications, limitations, recommendations for future research, and the overall conclusion. The purpose of this chapter is to provide a comprehensive understanding of how energy consumption and other macroeconomic factors influence industrial growth and to offer practical guidance for policymakers and researchers.

6.1 Summary of Findings

This study examined the impact of energy consumption on industrial growth in Pakistan, while controlling for trade openness, inflation, and labour force participation using annual time-series data from 1976 to 2024. The data were analysed through the Autoregressive Distributed Lag (ARDL) approach.

The results show that inflation fluctuated significantly over time, while industrial growth, energy consumption, trade openness, and labour force showed moderate stability with variations linked to economic conditions. The unit root test confirmed mixed integration orders, validating the use of the ARDL technique.

The ARDL bounds test confirmed a long-run relationship among all variables, indicating that they move together and jointly affect industrial growth in Pakistan. Energy consumption was found to have a key positive role in industrial growth, supporting the Energy-Led Growth Hypothesis.

Trade openness was also found to promote industrial growth through improved access to markets, investment, and technology. Inflation negatively affected industrial performance by increasing production costs and economic uncertainty. Labour force participation contributed positively by supporting industrial productivity through an available workforce.

Diagnostic tests confirmed the reliability of the model, showing no serial correlation or heteroskedasticity, normally distributed residuals, and stable parameters under the CUSUM test, indicating robust and consistent results for policy interpretation.

6.2 Contribution of the Study

This study contributes to the existing literature in several ways. First, it focuses specifically on industrial growth rather than overall economic growth, which distinguishes it from many previous studies conducted in Pakistan. While earlier research largely examined the relationship between energy consumption and aggregate GDP growth, this study investigates industrial value added as a direct indicator of industrial performance.

Second, the study incorporates important macroeconomic variables including trade openness, inflation, and labour force participation within a unified analytical framework. This provides a more comprehensive understanding of the factors affecting industrial growth in Pakistan.

Third, the study utilizes recent annual time-series data covering a long period from 1976 to 2024. The use of an extended dataset allows for a more reliable assessment of long-run economic relationships and structural changes in Pakistan's industrial sector.

Finally, the study provides empirical evidence that can assist policymakers in designing effective energy and industrial policies aimed at improving industrial productivity and sustainable economic development.

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6.3 Implications of the Study

The findings of this study carry important implications for economic planning and policy formulation in Pakistan.

The positive role of energy consumption highlights the necessity of ensuring a stable, affordable, and uninterrupted energy supply for industrial activities. Frequent energy shortages and rising energy costs can significantly reduce industrial productivity and discourage investment. Therefore, improving energy infrastructure should remain a national priority.

The results related to trade openness suggest that policies promoting international trade can support industrial expansion by providing access to larger markets, modern technologies, and foreign capital. However, trade liberalization should be accompanied by measures that strengthen domestic industries and improve their competitiveness.

The negative influence of inflation indicates the importance of maintaining macroeconomic stability. Persistent inflation increases production costs and creates uncertainty, which may discourage industrial investment. Therefore, effective monetary and fiscal policies are essential for sustaining industrial growth.

The positive role of labour force participation implies that investments in education, vocational training, and skill development programs can improve labour productivity and enhance industrial performance. Human capital development should be integrated into long-term industrial development strategies.

6.4 Beneficiaries and Commercialization of Research

The findings of this study can benefit several stakeholders.

Government institutions, including the Ministry of Energy, Ministry of Industries and Production, and economic planning agencies, can utilize the findings to formulate policies aimed at improving energy management and industrial development.

Industrial firms and private investors can benefit from understanding the importance of energy availability and macroeconomic stability in influencing industrial performance and investment decisions.

Academic researchers and students can use this study as a reference for future research related to energy economics, industrial development, and economic growth in developing countries.

International development organizations and policy institutions may also benefit from the findings when designing programs related to sustainable industrialization and energy sector reforms.

From a commercialization perspective, the study may support investment decisions related to renewable energy projects, industrial energy efficiency programs, technological modernization, and infrastructure development initiatives that contribute to industrial growth and economic sustainability.

6.5 Limitations of the Study

Despite its contributions, the study has certain limitations.

First, the analysis is limited to Pakistan and therefore the findings may not be directly generalizable to other countries with different economic structures and energy systems.

Second, the study uses annual aggregate data, which may not fully capture sector-specific variations within the industrial sector. Different industries may respond differently to changes in energy consumption and macroeconomic conditions.

Third, due to data availability constraints, the study focuses on a limited number of explanatory variables. Other potentially important determinants of industrial growth, such as technological innovation, foreign direct investment, infrastructure quality, institutional effectiveness, and energy prices, were not included in the model.

Fourth, the study relies on secondary data collected from the World Development Indicators database, and therefore the accuracy of the findings depends upon the reliability of the available data.

6.6 Recommendations for Future Research

Future research may extend this study by incorporating additional macroeconomic and structural variables such as foreign direct investment, renewable energy consumption, infrastructure, and technological development to gain a more comprehensive understanding of industrial growth determinants in Pakistan.

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Future studies may also conduct comparative or sector-specific analyses using advanced econometric techniques or cross-country data to explore differences in industrial performance and better capture dynamic and nonlinear relationships over time.

6.7 Conclusion

This study examined the relationship between energy consumption and industrial growth in Pakistan from 1976 to 2024. The results confirm a long-run relationship between energy consumption, trade openness, inflation, labour force participation, and industrial growth. Energy is found to be a key driver of industrial performance, along with important macroeconomic factors.

The study concludes that sustainable industrial growth in Pakistan depends on a stable energy supply, supportive macroeconomic conditions, stronger trade activity, and an effective labour force. Overall, improving energy management and economic policies is essential for long-term industrial development in Pakistan.

Author Contributions

Author participated in ideation, development, and writing the manuscript. All authors read and approved the final manuscript.

Conflict of Interest Statement

The author declare that there is no conflict of interest regarding the publication of this article.

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Informed Consent

Informed consent was obtained from all participants.

Data Availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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