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Analyzing the Relationship between Economic Growth, Industrial Development, and Environmental Sustainability in Pakistan: A Long-Run and Short-Run ARDL Analysis

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ABSTRACT

This study examines the effect of carbon dioxide (CO_2) emissions, industrialization, foreign direct investment (FDI) and population growth on economic growth in Pakistan over the period 1970-2025. The study uses the bounds testing approach of the Autoregressive Distributed Lag (ARDL) model as the variables are mixed order of integration, I(0) and I(1). To check the stationarity properties of the variables, unit root tests were performed before the estimation. The ARDL bounds test was applied to check the presence of a long-run relationship between the variables and the long-run and short-run coefficients were estimated by the error correction model (ECM). To test the reliability and robustness of the estimated model, several post-estimation diagnostic tests were conducted, such as the Jarque–Bera normality test, the Breusch–Godfrey serial correlation test, the Breusch–Pagan–Godfrey heteroskedasticity test, the Ramsey RESET specification test, and the CUSUM and CUSUMSQ stability tests. The diagnostic results showed that the model meets the classical regression assumptions: normally distributed residuals, no serial correlation and heteroskedasticity, proper model specification and stable coefficients across the sample period. The empirical results show that there is a long-run equilibrium relationship between the economic growth and the selected explanatory variables. The findings have significant policy implications for sustainable economic growth through environmentally responsible industrial development, productive foreign direct investment and effective population management. The study suggests that Pakistan's policy makers should implement balanced economic and environmental policies to promote sustainable industrialization, foreign investment in the environment-friendly sector and reinforce environmental laws for sustainable economic growth in Pakistan.

Keywords: *Economic Growth, CO_2 Emissions, Industrialization, Foreign Direct Investment, Population Growth, ARDL, Pakistan.*

INTRODUCTION

Economic growth is a key goal of any country as it is the basis for improving living standards, reducing poverty, creating jobs and increasing overall economic welfare. Sustained economic growth is especially significant for developing countries as it allows governments to boost public investment in education, health, infrastructure, and technological innovation, as well as enhance the quality of life of their citizens. Over the years, countries that have successfully transitioned to a new economy have seen a substantial rise in productivity, industrial output and per capita income. But, in addition to these economic gains, there are also serious environmental problems that have arisen as a result of the rapid industrialization and energy consumption. The constant rise in carbon dioxide (CO_2) emissions has become one of the most serious threats to sustainable economic development among these challenges. As a result, the link between economic growth, industrialization and environmental degradation has emerged as a focal point of environmental and development economics. In the past few decades, the global economy has gone through unparalleled economic growth, fuelled by industrialization, technological innovation, globalization, urbanization and growing international trade. These have significantly raised the income levels of the world and lowered extreme poverty in many parts of the world, but have also led to a significant decline in natural resources and environmental pollution. The use of fossil fuels like coal, oil and natural gas has risen due to industrial production, electricity generation, transportation, construction activities and growing urban settlements. These fuels are known to emit significant amounts of greenhouse gases (GHGs) into the atmosphere, including carbon dioxide (CO_2), which is the main driver of global climate change. Global warming, caused by the increase of greenhouse gases, has affected the climate system of the Earth, leading to higher temperatures, changes in precipitation, melting glaciers, sea-level rise, loss of biodiversity, and more frequent extreme weather events. The effects of climate change are not only environmental but also have direct impacts on economic development, public health, food security, agriculture, water resources and human welfare, making it one of the greatest challenges of the twenty first century. The scientific evidence shows that anthropogenic greenhouse gas emissions are the main cause of climate change and CO_2 is the most important greenhouse gas for the global emissions. This has led to a growing focus on the importance of sustainable economic growth, with a focus on reducing carbon emissions while maintaining economic development. International agreements such as the Paris Climate Agreement and the United Nations Sustainable Development Goals (SDGs) promote environmentally sustainable policies that aim to achieve economic growth while reducing environmental harm. The issue of economic growth and environmental protection is especially relevant for developing countries. The focus of developing countries remains on industrialization, infrastructure development, employment creation and poverty alleviation, unlike advanced economies. These development goals frequently involve significant increases in energy use and industrial output, and can also lead to increased carbon emissions. This means that policy makers are confronted with a challenging balance between economic growth and environmental quality. This relationship has thus emerged as one of the most significant fields of research in environmental economics and sustainable development. Industrialization has always been a key factor in the economic development of countries. The shift from agricultural economies to manufacturing and industrial production has helped countries to become more productive, to export more, to be technologically more advanced, to structurally transform their economies and to create more jobs. The experiences of the developed economies show that industrialization is one of the important drivers of long-term economic growth as it improves production efficiency, stimulates innovation and boosts value added manufacturing activities. Industrialization is still vital for structural transformation and for low productivity agriculture to be less important for developing countries. Although industrialization has a lot of economic advantages, it also has a lot of environmental disadvantages. Industrial production consumes vast amounts of electricity, fossil fuels, raw materials and transportation services, which all have a direct or indirect impact on carbon emissions. Steel, cement, chemicals, textiles, fertilizers, heavy engineering are some of the major industries that consume fossil fuels and are thus sources of GHGs. Increased industrial production leads to an overall rise in energy demand, which leads to increased CO_2 emissions unless cleaner technologies and renewable energy sources are used. Thus, industrialization brings both economic development and environmental sustainability opportunities and challenges. There are several viewpoints on the link between economic growth and environmental quality in economic theory. The traditional economic growth theories mainly focused on capital accumulation, labor productivity, technological progress and investment, and relatively neglected the externalities of the environment. But in modern environmental economics it is known that economic production produces desirable outputs like income and employment, and undesirable outputs like pollution and greenhouse gas emissions. This recognition has resulted in the creation of many theoretical models on the relationship between economic development and environmental degradation. The Environmental Kuznets Curve (EKC) hypothesis is one of the most influential theories in this field. The EKC suggests that environmental degradation actually worsens at the initial stages of economic development due to the countries' focus on industrial expansion, urbanization and economic growth. In this stage, environmental laws are typically lax, technology is not very efficient, and industries heavily depend on fossil fuels. With the rise of income, however, societies start to demand better environmental quality, governments tighten environmental laws, and firms start using cleaner production technologies. As a result, even as the economy grows, the level of pollution eventually drops. The inverted U-shaped curve between income and environmental degradation has been widely studied in the empirical literature, with mixed results in different countries and regions. The idea of sustainable development, which focuses on the need to consider economic, social and environmental goals together, is another important theoretical perspective. Sustainable development is a concept that calls for current economic activities to meet the needs of the present without jeopardizing the ability of future generations to meet their needs. This is because the long-term economic success relies on the protection of natural resources, ecological balance and reduction of environmental degradation. Sustainable industrialization thus promotes the use of energy efficient technologies, renewable energy sources, cleaner production processes and environmentally responsible business practices. Sustainable development is now being incorporated into the economic planning of governments globally, so that industrial development can take place while protecting the environment. Technological innovation is also an important factor in the relationship between industrialization and environmental quality. Technological developments in production, renewable energy, energy-saving machinery, waste management and pollution control equipment allow industries to boost productivity while minimizing environmental effects. Green technologies have proven to be very promising in reducing carbon emissions while maintaining the competitiveness of industry. As a result, research and development, technological modernization and innovation have become a key tool for sustainable economic growth. The relationship between economic growth and environmental sustainability has become more complex in the era of globalization. Globalization has led to a surge in industrial growth in many developing countries, through international trade, foreign direct investment, multinational production networks and global supply chains. Globalization is a means of transferring technologies, capital inflows and export growth, but can also lead to an increase in industrial pollution if environmental regulations are not sufficiently strict. Therefore, the linkages between economic openness and industrialization and environmental quality is becoming more relevant for policy makers interested in sustainable development strategies. As climate change has become an increasing concern, environmental sustainability has become a key part of national economic planning. The importance of including environmental aspects in economic policies to guarantee long-term development is increasingly acknowledged by countries. Investments in renewable energy, energy efficiency, sustainable transportation, cleaner manufacturing technologies and environmental governance have thus been a key part of development strategies globally. However, developing countries still have a lot of work to do, as economic growth is still largely reliant on energy-intensive industrial processes that emit a lot of carbon. In this wider global picture, Pakistan is a significant case study for the study of the dynamic interplay between economic growth, industrialization and CO_2 emissions. Over the last few decades, the country has seen a slow economic growth, a high population growth rate, growing urbanization and a growing industrial activity. These developments have helped to increase national income and employment, but have also increased energy demand and environmental pressures. Therefore, it is crucial to understand the effect of economic growth and industrialization on carbon emissions in Pakistan to formulate policies for sustainable development without compromising long-term economic growth. This study tackles these issues by examining the relationship between economic growth, industrialization and CO_2 emissions using the Autoregressive Distributed Lag (ARDL) modeling approach, which allows for estimation of both short-run dynamics and long-run equilibrium relationships between the variables. Pakistan is a developing economy with a multi-layered relationship between economic growth goals, industrial transformation, increasing energy demand, and environmental sustainability issues. Economic development has been a key priority of Pakistan's national policy agenda since independence. The country has implemented a number of economic reforms to promote industrialization, boost productivity, upgrade infrastructure, attract foreign investment and boost international trade. These efforts have helped to create some periods of strong economic growth, especially in times of industrial development and structural change. The economic development, however, has also created significant environmental challenges, primarily associated with the reliance on fossil fuels, accelerated urbanization, industrialization and consumption growth. The economic landscape of Pakistan has undergone a gradual shift from agriculture to diversified economy of industry and services. The industrial sector has been a key enabler of this change, with its impact on employment, export earnings, technology, and economic diversification. The major industrial activities in Pakistan are textiles, cement manufacturing, fertilizers, chemicals, steel, leather, food processing, and construction industries. Of these sectors, the textile industry is one of the major exporters, and the cement and construction industries have grown considerably as a result of the growing infrastructure development and urbanization. While industrialization has contributed to economic development, many industries still rely on energy-intensive production processes, posing challenges for environmental sustainability. The industrial development of Pakistan has been hampered by a number of structural problems such as energy shortage, lack of technological development, poor infrastructure, financial constraints and reliance on imported energy resources. The energy crisis in Pakistan over the past few years greatly impacted industrial productivity and economic growth. In response to these challenges, the government has been investing in energy generation projects, such as fossil fuel-based power plants, hydropower projects, and renewable energy projects. But fossil fuels still play a major role in Pakistan's energy mix, especially in the form of oil, natural gas and coal. This reliance on traditional energy sources has led to higher carbon emissions and environmental degradation. One of the most powerful pathways by which economic growth and industrialization affect CO_2 emissions is energy use. For economic growth, more energy is needed to fuel manufacturing, transportation, business operations, and consumer demand. Population growth, urbanization, industrialization, and increased income of households have all contributed to the growing electricity demand in Pakistan. Renewable energy resources like solar, wind and hydropower have been on the agenda for a number of years, but they are still not enough to replace the energy systems that are based on traditional fossil fuels. Consequently, there has been a persistent association between economic growth and rising energy use and GHG emissions. In recent years, the environmental impacts of Pakistan's development trajectory have become more apparent. Pakistan, although a small emitter of GHGs, is one of the most climate change sensitive countries. The country has been hit by extreme weather events such as catastrophic floods, extreme heat waves, droughts, altered rainfall patterns and glacier hazards. These environmental challenges have far-reaching impacts on agriculture, water resources, public health, infrastructure, and economic security. Despite the fact that agriculture is a significant part of the economy and job structure in Pakistan, the impacts of climate change are adding to the challenges of food security and rural livelihoods. The correlation between industrialization and CO_2 emissions in Pakistan is significant as industrial activities are a significant demand for energy. Fossil fuel energy sources and outdated machinery and production processes are common in manufacturing industries, leading to relatively high carbon intensity. Financial and technological barriers continue to hinder the uptake of cleaner technologies, energy efficient equipment and environmentally friendly production methods. Thus, industrialization has positive effects on economic development but its environmental impacts should be carefully assessed. Foreign direct investment (FDI) and trade growth have also had an impact on industrial growth and environmental impacts in Pakistan. Foreign investment may be beneficial to economic development in terms of bringing in new technologies, better managerial skills and higher industrial productivity. The impacts of FDI on the environment, however, are heavily dependent on the type of investment and the host country's regulatory framework. If environmental regulations are lax in the country, foreign investment can lead to higher pollution levels due to the pollution-intensive industries. On the other hand, investments in environmentally friendly technologies and renewable energy projects can help to promote sustainable industrial development. Hence, it is important to have a comprehensive knowledge of the overall linkage between economic growth, industrialization, investment and environmental quality for Pakistan's development strategy. Another important factor affecting the economic development-carbon emissions nexus is urbanization. Urbanization has been fast in Pakistan as a result of migration, concentration of industries and growing opportunities in the cities. The urbanization process raises the demand for transportation, housing, electricity, construction materials, and public infrastructure. Urban development can have a positive effect on the economy and the quality of life, but it can also lead to environmental issues such as higher energy use, traffic, waste generation and concentration of industry. Thus, it is essential to have effective urban planning and sustainable infrastructure development to minimize the environmental impacts of urban growth. There has been a wide range of empirical studies on the link between economic growth and CO_2 emissions, with results varying by country and region. There have been several studies that have shown that economic growth leads to environmental degradation due to the fact that as income rises, there is an increase in industrial production, energy consumption and resource exploitation. The results confirm the classic theory that environmental degradation is likely to occur in early phases of economic development in developing countries. Other studies, however, have evidence in favor of the Environmental Kuznets Curve hypothesis, which states that economic growth can lead to environmental improvement at a later stage through technological progress, structural change and increased environmental awareness. In Pakistan, empirical evidence on the economic growth-carbon emissions nexus is mixed. Empirical evidence in Pakistan on the economic growth-carbon emissions nexus is mixed in previous studies. The economic growth is also believed to have a significant impact on CO_2 emissions in Pakistan, where fossil fuel consumption and energy-intensive industries are prevalent, according to some researchers. Other research indicates that over time, environmental pressures can be lowered through technological advances, renewable energy use, and economic restructuring. Likewise, the impact of industrialization on emissions is uncertain, as industrial expansion can lead to greater emissions due to increased energy consumption, or to lower emissions due to technological advances and efficiency. The non-conforming results suggest the need for additional research with more up-to-date data and reliable econometric methods. It is especially relevant for policy makers to know if economic growth and industrialization have short-term or long-term impacts on CO_2 emissions. Pakistan may require more stringent environmental laws, cleaner energy policies and investments in green technologies if the economic growth is significantly driving up emissions. Otherwise, policies should aim at promoting technological change and sustainable industrial development if economic development is found to lead to better environmental quality at a later stage. The econometric analysis of the relationship between economic growth, industrialization and CO_2 emissions is complex and needs to be analyzed using an econometric model that can capture both short-run fluctuations and long-run equilibrium relationships. When using traditional regression methods, they can yield inaccurate results with variables that have different statistical characteristics, such as time-series variables. Therefore, advanced econometric methods are necessary to determine the dynamic interactions among economic variables and environmental indicators. The ARDL modeling approach is suitable for analyzing the economic and environmental relationships in this context. The ARDL technique can be used to examine variables that are stationary at level I(0) and first difference I(1). It also offers estimates of both short-run and long-run relationships, which is useful for developing economies where macroeconomic variables may have structural changes and fluctuations over time. To analyze the relationship between economic growth, industrialization and environmental degradation, an econometric methodology that can incorporate complex dynamic interactions between macroeconomic variables is needed. Economic variables like GDP, industrial production, energy use, and carbon emissions tend to be volatile, structurally changing, and less or more integrated. The use of traditional regression techniques on such time-series data could lead to unreliable estimates since non-stationary variables can create spurious relationships. Thus, it is important to choose an appropriate econometric technique to get valid and meaningful empirical results. The Autoregressive Distributed Lag (ARDL) modeling approach of Pesaran, Shin, and Smith (2001) has received a lot of attention in empirical economic research because of its flexibility and efficiency in this respect. The ARDL method has several merits over the conventional cointegration methods. First, it can be used when the explanatory variables are integrated at different orders, namely, level stationary I (0) and first difference stationary I(1), with none of the variables being second difference stationary I(2). This feature makes ARDL a very appropriate model for developing economies where macroeconomic indicators often exhibit mixed integration properties. Second, the ARDL model can be applied to relatively small sample sizes, which is crucial for country level studies with limited annual observations. Third, ARDL estimates both short-run dynamics and long-run equilibrium relationships, enabling researchers to study both short- and long-term impacts of economic variables on the environment. The ARDL Bounds Testing procedure is used to check the existence of a long-run relationship between the variables under consideration. If the calculated F statistic is greater than the upper critical value, the null hypothesis of no cointegration is rejected, which means that there is a stable long run relationship. Following confirmation of cointegration, the long-run coefficients and short-run error correction model (ECM) can be estimated. The error correction term is the term that tells us how quickly short-run deviations are corrected to long-run equilibrium. Thus, ARDL offers a holistic perspective of the interaction of economic shocks, industrial growth, and environmental pressures over time. The ARDL methodology is especially suitable for Pakistan due to the structural changes in the economy, such as the changes in industrial policy, energy sector reforms, trade liberalization and infrastructure development initiatives. Such changes can affect the economic growth-environmental quality nexus. The ARDL method enables the study to account for these dynamic relationships, taking into account immediate responses and longer-term adjustments. This is more useful than the static models that do not consider time-varying interactions between economic variables. Despite the extensive research on the economic growth and environmental degradation, there are some important gaps in this context especially in the case of Pakistan. First, previous empirical research has yielded conflicting results on the relationship between economic growth and CO_2 emissions. While some research suggests that economic growth is associated with increased emissions due to increased energy use and industrial activity, others have found that technological progress and structural change can enhance environmental quality. The conflicting results suggest that the link between economic development and environmental sustainability is not clear. Secondly, the majority of the previous studies have been based on the energy consumption and its impact on CO_2 emissions, and have relatively limited attention to the specific contribution of industrialization. Industrialization is an integral part of Pakistan's development process and its environmental effects need to be explored in detail. Because industrial production plays an important role in economic growth and energy consumption, it is important to know how it affects carbon emissions to design sustainable industrial policies. Third, much of the previous literature has focused on the study of environmental degradation with traditional econometric methods without taking into account the difference between the short run and the long run. Economic growth and industrial activities can, however, have immediate impacts on emissions that are different from their longer-term impacts. For instance, industrial growth could lead to higher emissions in the short-term as more fossil fuels are used, but over time, technological advancements and efficiency gains could lower emissions. Thus, it is important to differentiate between short- and long-run relationships to gain a fuller understanding of the interactions between the economy and the environment. Fourth, the country specific empirical evidence is important because of the growing vulnerability of Pakistan to climate change. While international studies offer good theoretical background, the economic structure, energy system, industrial composition and institutional environment of each country is different. Pakistan's dependence on fossil fuels, high population growth rate, growing industrialization and climate vulnerability make it a significant case to explore the sustainability of economic development. New empirical evidence is needed to inform good policy-making and to guarantee that economic growth policies are consistent with environmental goals. To fill these research gaps, this study investigates the relationship between economic growth, industrialization and CO_2 emissions in Pakistan for the period 1951-2011 by employing ARDL modeling framework. The study adds to the literature in the following ways. First, it offers empirical evidence on the dynamic relationship between economic development and environmental sustainability in a developing economy context. The study is limited to Pakistan, which helps to gain insight into the environmental impacts of industrial growth in a country in structural transformation. Secondly, the study is methodologically valuable as it uses the ARDL method to estimate both short-run and long-run relationship between the variables. The ARDL model is more informative than simple correlation analysis and static regression models because it gives insights into the adjustment process and the long-term equilibrium relationship between economic activities and environmental indicators. This methodological approach enhances the confidence and policy relevance of the results. Thirdly, the study has policy implications for sustainable development in Pakistan. If economic growth and industrialization are identified as a significant source of CO_2 emissions, then policy makers should encourage cleaner production processes, the use of renewable energy, energy efficiency and tougher environmental legislation. Industrial policies should promote the modernization of production technologies and help companies to shift to low-carbon production systems. Likewise, energy policies should aim to decrease reliance on fossil fuels and increase the capacity of renewable energy. If, on the other hand, economic growth can lead to better environmental outcomes via technological change and structural change, policies should aim to speed up the economic modernization and innovation. Research and development, green technologies, and environmentally friendly industries can contribute to Pakistan's economic growth without compromising on its carbon intensity. Thus, it is crucial to understand the economic growth, industrialization and CO_2 emission relationship to formulate balanced policies to meet both economic and environmental goals. This research's findings are also applicable in the backdrop of Pakistan's international climate commitments. Pakistan is a signatory of the global climate agreements and has pledged to cut down on GHG emissions, build climate resilience and foster sustainable development. To accomplish these objectives, there must be evidence-based policies that acknowledge the connection between economic activities and environmental outcomes. Robust econometric methods can be used to conduct empirical studies that can offer useful insights for policymakers looking to balance economic growth and climate change mitigation. To sum up, economic growth and industrialization continue to be the key pillars of Pakistan's development but the environmental impacts of these processes should not be overlooked. The challenge is not to slow down economic growth but to make sure it takes place in sustainable ways. It is therefore essential to understand the link between industrial growth, expansion and carbon emissions to develop effective environmental and economic strategies. This study has applied ARDL modeling technique to analyze the short-run and long-run relationship between economic growth, industrialization and CO_2 emissions in Pakistan. The outcomes are anticipated to be useful for academic research and for offering practical suggestions for sustainable economic development and environmental protection.

Scope of Problem

Economic growth and industrialization are the basic determinants of economic development, especially in developing countries like Pakistan. In recent decades, Pakistan has adopted several economic policies to boost the industrialization process, expand production capacity, boost trade, attract investments and enhance infrastructure. These have helped to drive economic growth and structural change, moving the economy away from traditional agriculture and towards more diversified industrial and service sectors. The economic growth and industrialization, however, have also created significant environmental problems, especially in the form of increased energy use and CO_2 emissions. The growing industrialization has created a high demand for energy, transportation and natural resources in Pakistan. The nation's energy system is still largely reliant on fossil fuels, such as oil, coal and natural gas, and as a result, economic and industrial development has been paralleled by rising greenhouse gas emissions. Industrial production, electricity generation, transportation and construction are now significant contributors of carbon emissions. Industrialization has provided jobs, increased production and added to the national income but its environmental effects have raised concerns about the sustainability of Pakistan's development trajectory. The significance of CO_2 emissions in Pakistan has been increased due to climate change. Pakistan is a country with relatively low GHG emissions, but it is also one of the most vulnerable countries to the impact of climate change. Substantial economic and social risks have been caused by rising temperatures, irregular rainfall, severe floods, droughts, glacier melting and water related issues. These climate events have adverse impacts on agricultural productivity, infrastructure, public health and overall economic stability. Thus, the issue of economic growth without worsening environmental degradation has become a policy challenge for Pakistan. Pakistan is in a dilemma as it requires economic growth and industrialization for poverty alleviation, job creation and betterment of living standards but at the same time, it may lead to environmental degradation due to increased energy consumption and CO_2 emissions. The question is whether the economic growth and industrial development automatically result in environmental degradation or can sustainable economic transformation help Pakistan grow and cut carbon emissions. There is still a lack of clarity in the theoretical and empirical relationships between economic growth, industrialization and CO_2 emissions. The Environmental Kuznets Curve (EKC) hypothesis suggests that environmental degradation can worsen in the initial phases of economic growth as countries use resource-intensive production processes and fossil fuel energy systems. Once a certain threshold of economic development is achieved, however, environmental pressures can be lowered due to technological progress, environmental consciousness, institutional quality and cleaner production. Although much research has been conducted on this relationship, there is still no clear evidence, especially for developing economies. Some studies claim that economic growth leads to the higher CO_2 emissions, others that economic development can lead to environmental improvement at some extent. The impact of economic growth and industrialization on carbon emissions has been found to be mixed in the past in the context of Pakistan. A number of studies highlight that the reliance on traditional energy sources and growth of energy intensive industries in Pakistan has led to environmental degradation. Other research suggests that technological progress, the use of renewable energy and structural economic change can diminish the environmental consequences of growth. The conflicting results suggest the need for additional research with proper econometric methods that are able to account for short run fluctuations and long run relationships. The other research problem is that there are many studies that only look at energy consumption as a factor for CO_2 emissions and do not consider the role of industrialization as a separate factor. Industrialization is an integral part of Pakistan's economic development policy and its environmental impact needs to be thoroughly studied. Carbon emissions are affected by industrial activities not only by the direct use of fuel but also by the production process, technology, resource use and industrial efficiency. Hence, a detailed study of industrialization and its relation with economic growth is required to grasp the environmental issues in Pakistan. In addition, some previous empirical studies have been based on the conventional regression method which may not be suitable for the time-series nature of macroeconomic variables. Economic growth, industrial production, and CO_2 emissions can have trends, structural changes, and varying degrees of stationarity. Failure to address these econometric concerns could lead to inaccurate estimates and poor policy decisions. Hence, a strong analytical tool is needed to analyze the dynamic relationship between economic growth, industrialization and environmental degradation. The Autoregressive Distributed Lag (ARDL) modeling technique is an effective solution to these methodological problems. The ARDL method is different from the traditional method in that it can estimate both short run and long run relationships between variables with different orders of integration, as long as the variables are not integrated more than once. It is especially appropriate for developing economies that have fewer observations and structural economic changes. The aim of this study is to use ARDL modeling to find out whether economic growth and industrialization have any significant effect on CO_2 emissions in Pakistan and if there is any long run relationship between these variables. The primary issue that this study aims to solve is the absence of clear empirical evidence of the relationship between economic growth and industrialization with environmental sustainability in Pakistan. Economic development is necessary to enhance welfare and reduce poverty, but rapid industrial growth and reliance on fossil fuels can have long-term environmental consequences. Policymakers can be misled if they don't understand these connections, and they can be misled if they design policies that are supposed to help both the economy and the environment. This study is an attempt to address this research gap by examining the dynamic relationship between economic growth, industrialization and CO_2 emissions in Pakistan through the ARDL modeling framework. The results of the study will give valuable information on the sustainability of Pakistan's development path and the need for policy measures to encourage cleaner industrial development, energy efficiency and sustainable economic transition. This study provides empirical an evidence of the relationship between economic development and environmental quality, which helps to advance the discussion on sustainable development in developing economies. In developing countries, the link between economic growth, industrialization and environmental sustainability is gaining significance. Sustained economic growth and environmental protection are significant policy challenges for Pakistan. The importance of this study is that it gives empirical evidence to the issue of whether the current economic and industrial development path of Pakistan is environmentally sustainable or not. Academically, this study adds to the body of knowledge on environmental economics by offering empirical evidence in a developing country setting. There are many studies that have examined the link between economic growth and carbon emissions, but the results are not conclusive, especially with regard to the impact of industrialization. This research is specific to Pakistan, thereby contributing to the understanding of the impact of economic transformation on environmental outcomes in economies with high population growth, energy dependency and industrialization. Methodologically, the study is valuable because of the use of ARDL modeling to study the short-run and long-run relationships between economic growth, industrialization, and CO_2 emissions. The ARDL model is able to give reliable estimates because it deals with the problem of mixed integration orders and small sample size. This method enables the study to give more reliable evidence for the dynamic interactions between the variables. The results of this study are relevant to policy makers at the government level, environmental policy makers and economic planners. The role of economic growth and industrialization in carbon emissions can be understood to help the policy makers to design effective policy measures to promote sustainable industrial development. If industrial development is identified as a major source of emissions, policies focusing on cleaner technologies, renewable energy, energy efficiency and environmental policies will be necessary. The study also has implications for Pakistan's Sustainable Development Goals (SDGs) specifically SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure) and SDG 13 (Climate Action). The results can help policy makers create policies that promote economic growth while protecting the environment. Furthermore, the research provides insights for industries by highlighting the importance of technological modernization, efficient energy utilization, and environmentally responsible production practices. Sustainable industrial development can enhance competitiveness while reducing carbon intensity. In general, this study offers a thorough knowledge of the relationship between economic growth, industrialization and CO_2 emissions in Pakistan. The results obtained from ARDL modeling can be used to formulate policies that promote economic growth and sustainability in the long run.

LITERATURE REVIEW

Economic Growth, Environmental Sustainability and Development Dynamics

Economic growth has been a long-standing goal of the developing economies, as it is a means to increase incomes, create jobs, reduce poverty, build capital, and improve living standards. Economic growth helps countries to grow their productive capacity, develop infrastructure, create more investment opportunities, and boost socioeconomic development. Economic growth, however, is not an autonomous process, but is linked to rising energy use, industrialization, resource use and environmental stress. Economies expanding, energy, transportation, manufacturing demands and natural resource demands all increase, potentially leading to environmental issues, especially carbon dioxide (CO_2) emissions. With the rise of concerns about climate change, global warming and environmental degradation, the link between economic growth and environmental sustainability has been gaining more and more attention among economists, policy makers and researchers. Environmental quality is affected by economic activities in several ways. Economic development can also put more strain on the environment by boosting production, energy consumption and resource extraction. Conversely, economic development can lead to environmental improvement via technological innovation, cleaner production processes, energy efficiency and improved environmental management systems. Thus, the economic growth-environmental quality relationship is complex and is influenced by the stage of development, the economic structure, technological capacity, energy sources, and institutional policies. There is a trade-off between economic growth and environmental protection that is challenging in developing countries. In the initial phase of development, the governments are more interested in industrialization, employment generation and income generation. Consequently, economic activities are often reliant on fossil fuels and energy-intensive sectors, leading to higher carbon emissions. But in more developed economies, technological progress, structural change and environmental consciousness can diminish environmental pressures. This poses an important research question: does economic growth lead to environmental degradation or does it eventually result in environmental improvement? Economic growth and environmental sustainability are especially relevant for Pakistan, as the country has undergone substantial economic change in the past few decades. Industrialization, foreign investment, population growth, urbanization, and energy demand are the key factors that have been observed in Pakistan. These advancements have helped in the economic growth by providing more production capacity, jobs and investments. They have also caused environmental problems by generating excess greenhouse gas, air pollution and straining natural resources. Industrialization has been a key pillar of Pakistan's economic development policy. Industrial development improves economic performance in terms of productivity, technological development, job creation and structural change. But industrial processes, especially in manufacturing, energy generation, construction and heavy industries, frequently rely on fossil fuels and energy-intensive production processes. As a result, industrial development could lead to higher CO_2 emissions and environmental degradation. Thus, it is crucial to grasp the importance of industrial development for economic performance and environmental outcomes in order to develop sustainable development policies. Foreign direct investment (FDI) is another important factor influencing economic growth and environmental sustainability. FDI is a source of funding, boosts capital formation, brings in new and advanced technologies, raises productivity and generates jobs. Foreign investment is often welcomed in developing countries, as it helps in industrial development and enhances economic capacity. But the impacts of FDI on the environment are not clear. Foreign investment can help to enhance environmental quality through technology transfer, efficient management practices and cleaner production techniques. On the other hand, it can lead to more pollution if the multinational companies move the polluting industries to countries with less stringent environmental laws. Population growth also contributes to the economic and environmental conditions. An expanding population can contribute to economic growth through the provision of more labor, more domestic markets and investment opportunities. Education, skills development and employment opportunities can help to support a larger workforce to increase production capacity and to help promote economic development. But rapid population growth can also pose problems in terms of energy consumption, resource demand, urbanization and environmental pressure. Hence, population growth is a challenge and opportunity for developing countries like Pakistan. The overall impact of economic growth, industrialization, FDI, population growth and CO_2 emissions gives a complete picture of the development path of Pakistan. It is essential to consider these factors together, as economic performance is influenced by a number of interrelated factors, rather than just one. Economic growth is possible in a country through the expansion of industry and foreign investment, but sustainability is only possible if the growth is not accompanied by excessive environmental damage.

THEORETICAL SUPPORT

Environmental Kuznets Curve (EKC) Hypothesis

The Environmental Kuznets Curve (EKC) hypothesis is one of the most influential theories on the link between economic growth and environmental degradation. The theory suggests that environmental degradation initially increases during the early stages of economic development but decreases after an economy reaches a certain level of income. This relationship is shown as an inverted U curve between economic growth and environmental degradation. The EKC theory states that the pollution levels tend to rise in the early stages of economic development in developing countries, as the economy is primarily engaged in industrial growth, resource exploitation, and energy consumption. Environmental issues are not given much attention at this stage as governments focus on economic development, employment generation and poverty alleviation. However, as income rises, societies become more concerned about environmental protection, which results in more stringent regulations, technological advancements and increased use of cleaner production systems. The EKC hypothesis is based on three primary effects of economic growth and environmental quality. The first is the scale effect, which suggests that as the economy expands, production activities, energy use and emissions rise. The scale effect is dominant during early development stage due to the need for more resources to produce more output. The second is the composition effect, which is the shift from an agriculture-based economy to an industrial and service-based economy. Pollution can be higher in the early stages of structural transformation as industries expand, but in the long run, economies can move to less polluting industries and service sectors. The third is the technology effect, which refers to the increased technological innovation, energy efficiency, use of renewable energy and environmental management that occurs with higher income levels. Economies can be made more productive and less damaging to the environment through technological progress. The EKC hypothesis has been extensively studied in various countries, but the evidence is inconclusive. There are some studies that suggest an inverted U-shaped relationship between economic growth and environmental degradation, and others that suggest a positive relationship between income growth and emissions. These differences could be due to differences in energy structure, industrial development pattern, technological capacity, institutional quality, and environmental policies. The EKC framework is very applicable to Pakistan as the country is still in the developing phase with rising industrialization, energy consumption, and economic transformation. It is important to know if Pakistan is moving towards a situation where economic growth can help improve the environment to design effective sustainable development policies.

Endogenous Growth Theory & Sustainable Economic Development

The endogenous growth theory is an important theoretical framework for studying the linkage between economic growth, technological progress, investment and environment. Endogenous growth theory is an alternative to traditional growth theories, which treat technological progress as an exogenous variable, and instead focuses on the endogenous processes of innovation, knowledge accumulation, human capital formation, and research. From this viewpoint, economic growth depends on the growth of physical capital as well as the growth of technology, productivity, and knowledge production. The importance of endogenous growth theory for environmental sustainability is the contribution of technological progress. Growth can be innovative, efficient and environmentally friendly and thus not lead to environmental degradation. Technological development can lower energy intensity, increase resource efficiency and encourage the use of renewable energy sources. Thus, research and development, human capital and technological infrastructure investments can contribute to the economic growth of developing countries without increasing environmental pressure. Endogenous growth theory emphasizes the need for technological change and industrialization in developing countries like Pakistan. Economic growth using traditional production processes and energy systems can exacerbate environmental issues, and growth driven by technological innovation can enhance productivity and lower emissions. Thus, policies promoting innovation, technology adoption, skill development and industrial upgrading are crucial for sustainable economic development. Foreign direct investment is also related closely to endogenous growth theory, as multinational companies can transfer advanced technologies, managerial skills, and production knowledge to the host economies. FDI can boost domestic productivity through the introduction of modern production methods and through competition among domestic firms. The environmental impacts of technology transfer, however, are dependent on the type of foreign investment. Investment in clean technologies and sustainable industries can have a positive impact on environmental outcomes, while investment in polluting industries can have a negative impact on environmental outcomes. In the Pakistani context, endogenous growth theory proposes that economic development should not only be about output growth, but also quality and sustainability of production. Pakistan can attain higher economic growth and mitigate environmental issues through investments in clean energy, industrial efficiency, technological innovation and human capital development.

Pollution Haven and Pollution Halo Hypotheses

Foreign direct investment has emerged as a significant part of the economic development policies in developing countries due to its ability to supply financial resources, promote industrial development and technology transfer. But the effects of FDI are still subject to debate. The foreign investment and environmental quality relationship is explained by two major theories: the Pollution Haven Hypothesis and the Pollution Halo Hypothesis. The Pollution Haven Hypothesis proposes that multinational firms might shift pollution-intensive industries from developed nations to developing economies with less stringent environmental laws and lower production costs. From this point of view, developing countries trying to attract foreign investment can lower environmental requirements, which will be beneficial for polluting industries. Consequently, FDI inflows can lead to an increase in industrial production, fossil fuel use and carbon emissions. This is especially true for developing countries where economic growth policies tend to focus on industrial growth and job creation. Foreign investment in manufacturing, energy, chemicals and heavy industries can put further pressure on the environment. In countries with weak regulatory capacity, pollution levels may be higher due to the lack of environmental costs being taken into account in investment decisions. The Pollution Haven Hypothesis does not, however, fully explain the link between FDI and environmental outcomes. The Pollution Halo Hypothesis, which posits that foreign investment can enhance environmental quality by transferring technologies, better management practices and international environmental standards, is an alternative view. Developed country multinational companies may also have more sophisticated technologies and environmentally friendly production processes that can enhance the environmental performance of host economies. FDI can promote the adoption of cleaner technologies and production efficiency of domestic firms through competition and knowledge spillovers. Foreign companies can also bring in improved environmental management and help in sustainable industrial development. Thus, the environmental effects of FDI are influenced by the nature of the investment, the industrial composition of the host country, the regulatory framework, and the technological capabilities of the host country. The contribution of FDI in the economic and environmental development of Pakistan is of special significance. Foreign investment has helped in the development of industries, infrastructure, energy and economic activity. But, the lack of environmental regulation, technological constraints, and reliance on fossil fuels can affect the potential of FDI to be a source of environmental pressure or sustainable development. Hence, the effect of FDI on economic growth with the consideration of environmental factors is important for policy making.

Economic Growth & Sustainable Development

Another important framework for analyzing the link between economic growth and environmental protection is sustainable development. The idea is that economic development must meet the needs of the current generation without jeopardizing the ability of future generations to meet their needs. Sustainable development is concerned with balancing economic development, social development and environmental protection. Sustainable development is a great challenge for developing countries as economic growth is closely linked to industrial growth, energy use and resource exploitation. Economic growth is essential to poverty reduction, living standards and job creation but can lead to environmental degradation and depletion if it is not managed. In this aspect, this is a challenge for Pakistan because all the three pillars of economic development, energy demand, industrialization and urbanization have been linked with it. The reliance on fossil fuels in the country for electricity generation, transportation and industrial production has led to a rise in carbon emissions. Hence, sustainable economic development should be achieved by shifting to cleaner energy sources, increasing energy efficiency, adopting environmentally-friendly industrial processes and implementing effective environmental legislation. The term sustainable development does not mean that economic growth must be curtailed, but that the quality and efficiency of economic growth must be enhanced. Technological innovation, the use of renewable energy, efficient resource use, and improved institutional frameworks can make economic growth environmentally sustainable. Therefore, the policies must encourage industrial development and foreign investment should also take environmental sustainability into account.

Economic Growth and CO_2 Emissions

Economic growth and CO_2 emissions have been studied extensively in the field of environmental economics. Economic growth typically leads to an increase in the volume of goods and services produced, transportation demand, industrial production, and energy use. Many developing countries are dependent on fossil fuels, and economic growth tends to lead to increased carbon emissions. One of the primary ways in which economic growth impacts environmental quality is by influencing energy use. There is a lot of energy needed for industries, transportation systems, electricity generation and households. Countries with primarily coal-based, oil-based, and natural gas-based energy systems can experience a rise in greenhouse gas emissions as a result of increased economic activity. In developing countries, the environmental pressure is likely to be greater in the initial phases of economic development, when the emphasis is on industrialization and income generation. In this phase, governments may not be as focused on environmental protection because of scarce resources and development issues. Technological improvement, environmental awareness and structural transformation, however, could decrease the intensity of emissions as economies mature. This is a complex relationship that is evident in Pakistan's economic development experience. Industrialization, energy use, and infrastructure development have contributed to economic growth. But the use of fossil fuels has led to environmental issues. Carbon emissions have risen to a significant level from electricity generation, transportation, manufacturing and urban development. The correlation between GDP growth and CO_2 emission in Pakistan is still a research question as the country requires economic growth and mitigation of environmental risks. This relationship can be used to help inform policy design to encourage economic growth without exacerbating environmental degradation

Industrial Growth and Economic Performance

Industrialization has been viewed as a key factor of economic growth in the past. The industrial sector plays a role in economic development through production capacity expansion, productivity, job creation, export promotion, and technological development. Industrialization is a goal of developing countries because it can help them make the transition from traditional agriculture to modern industrial and service-based economies. Industrial development can affect economic growth in a number of ways. First, industries generate more production activities and value addition to the national output. Second, industrial growth promotes investment in infrastructure, technology and human capital. Third, manufacturing industries establish linkages with other sectors by stimulating demand for raw materials, transportation, finance and services.

Industrialization has been a key factor in the economic development of Pakistan. Employment, exports and economic diversification have been driven by key industrial sectors such as textiles, manufacturing, construction, energy production and engineering. Industrial development has also facilitated urbanization and technological development. But industrialization can bring environmental problems if it relies on inefficient technologies and fossil fuels. Cement, steel, chemicals and manufacturing are among the energy-intensive sectors that are significant emitters of carbon. Thus, the connection between industrial development and economic development is not without economic advantages and environmental disadvantages. Cleaner technologies, efficient energy systems and environmentally responsible production methods are essential for the sustainability of industrial development. Innovation and resource efficiency should be a part of modern industrialization, not only to boost production but to minimize environmental impacts.

Industrialization & CO_2 Emissions

Industrialization is regarded as one of the most significant factors that affect environmental conditions due to the high energy consumption and resource utilization that are needed for industrial activities. Carbon emissions are significant in manufacturing industries, construction works, mining and electricity generation because of their reliance on fossil fuels. Increased energy demand due to growth in industrial production can lead to increased GHG emissions, especially in developing countries where energy systems are predominantly dependent on traditional sources. The scale effect is a way to understand the relationship between industrialization and environmental degradation. The more an economy produces, the more energy, raw materials, transport and industrial infrastructure it requires. This expansion leads to higher emissions when the production is based on carbon intensive energy sources. This is a challenge that developing economies face, as industrialization is seen as a prerequisite for poverty alleviation, job creation and economic transformation, and environmental issues are given relatively little consideration in the early stages of development. The structure and technology of industrial activities are important factors in the environmental impact of industrialization. Economies with a strong reliance on heavy industry (steel, cement, chemicals, and energy production) tend to have higher emissions than economies with a strong focus on advanced manufacturing, technology intensive industries and services. Thus, the environmental costs of economic growth can be lowered by structural transformation to cleaner industries. Technological development has a significant impact on minimizing the environmental impacts of industrial development. The use of modern production technologies, energy-efficient machinery, integration of renewable energy, and enhanced waste management systems can lower carbon intensity and boost environmental performance. But financial and technological constraints are often present in developing countries that restrict their capacity to implement environmentally friendly industrial practices. Industrialization has played a significant role in the economic development of Pakistan, by providing jobs, expanding exports and enhancing production capacity. But the rapid industrialization has also led to a rise in energy demand and dependence on fossil fuels. The industrial sectors like textiles, cement, manufacturing and energy production have been responsible for the increase in carbon emissions. Thus, it is crucial to understand the linkages between industrial growth, economic performance and environmental sustainability in order to design effective industrial policies.

Foreign Direct Investment and Economic Growth

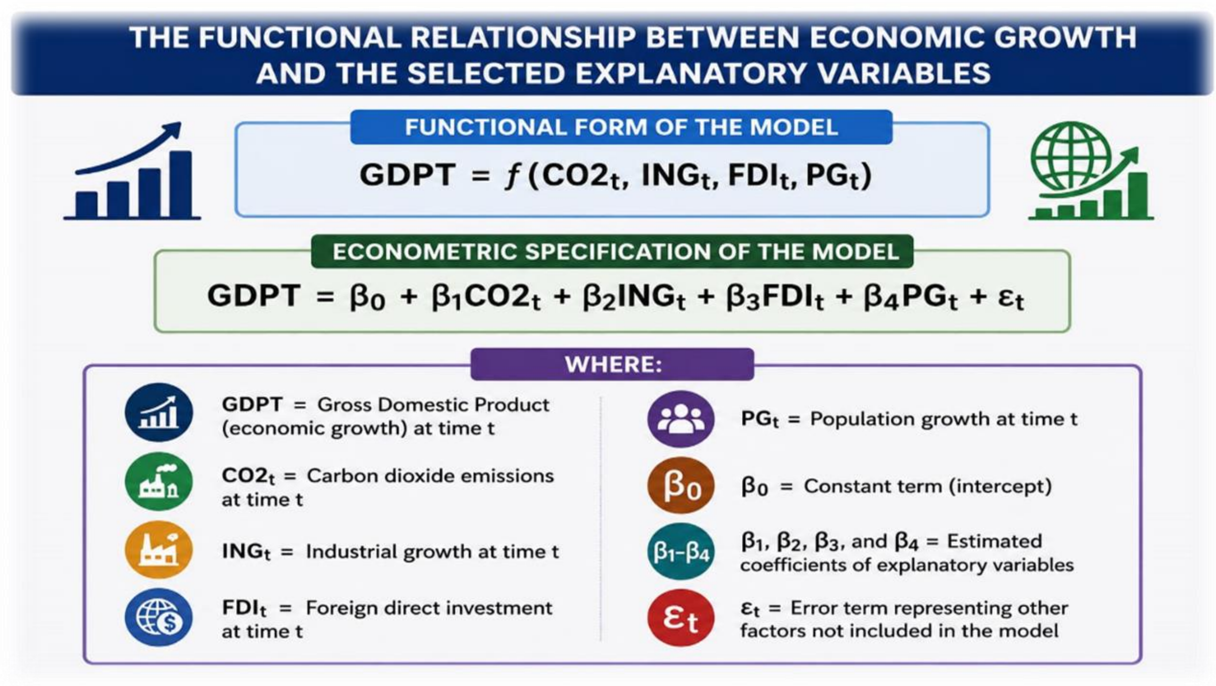
Foreign direct investment is known to be a key source of economic development, especially in developing countries where domestic resources are limited for large investments. FDI can promote economic growth through the following channels: providing capital, expanding productive capacity, generating jobs, enhancing technological capacity, and integrating into international markets. FDI can contribute to economic growth in a number of ways. Foreign investment adds to domestic saving and boosts investment in productive industries. Secondly, multinational firms bring in new technology, management skills, and international business methods that enhance productivity. Third, FDI leads to competition by encouraging domestic companies to become more efficient and use more efficient production processes. The growth effect of FDI, however, is related to the economic situation of the host country. Foreign investment is more likely to benefit countries with better institutions, infrastructure, human capital, and macroeconomic conditions. Economies with poor institutions and low technological capacity, on the other hand, may not reap as many benefits from FDI. To attract foreign investment, Pakistan has implemented several policies, including in the energy, telecom, manufacturing, and infrastructure sectors. While FDI has helped to drive industrial growth and economic activities, political instability, regulatory issues, energy scarcity and economic instability have hampered the capacity of foreign investment to deliver sustained growth. Thus, the link between FDI and economic growth is not necessarily automatic. The quality of the FDI, its sectoral allocation, institutional capacity, and the capacity of domestic firms and workers to absorb foreign knowledge and technology are critical to the effectiveness of FDI. The study of the role of FDI in economic growth is significant for Pakistan as foreign investment is still a vital part of the economic development strategies.

Population Growth & Economic Development

Population growth has been regarded as one of the key factors of economic development for a long time. Population growth and economic performance are linked, but the link is complex, as population growth can be an opportunity or a challenge. Population growth can be a positive force for economic growth by providing more labor, more consumers, and more investment opportunities. The demographic dividend approach holds that countries can grow their economies more rapidly if a large working-age population is able to be productively engaged and nurtured through education, health and skills. A young and growing workforce can boost productivity, innovation and economic growth. But, a high population growth rate can also pose serious economic problems. If population growth is outpaced by the ability of an economy to create jobs, it can result in unemployment, poverty, strain on infrastructure, and lower standards of living. High population levels also drive up the demand for energy, housing, transportation, food production and industrial products, putting further pressure on environmental resources. The relationship between population growth and environmental degradation is particularly important in developing countries. The more people, the more consumption patterns and the more resources that are needed, the more carbon emissions may be generated. Energy demand for transportation, electricity, and industrial activities increases as population size expands. But the environmental consequences of population growth are influenced by income, consumption, technology and environmental policies. Demographic factors are significant in economic planning for Pakistan as it has seen a rapid population growth over the last few decades. The population growth has led to an increase in the number of people employed and the size of the domestic market, but has also presented challenges in terms of employment creation, resource management, urbanization and environmental sustainability. Hence, the factors of economic growth should be analyzed in the context of population growth.

Data Estimation Methods

The quantitative time-series econometric approach is used to analyze the determinants of economic growth in Pakistan by studying the effect of carbon dioxide emissions, industrial growth, foreign direct investment and population growth. The data for the study is from the World Development Indicators (WDI) World Bank database and is annual data from 1970 to 2025. The chosen time frame offers a full picture of Pakistan's economic evolution, industrial growth, foreign investment patterns, population shifts, and environmental shifts in over 50 years. The empirical analysis is performed with the help of Autoregressive Distributed Lag (ARDL) model of Pesaran et al. (2001). The ARDL method is used because it can be used to study both short-run and long-run relationships between variables and allows variables to be integrated at different orders, I(0) and I(1). The ARDL framework is also superior to the traditional cointegration methods in terms of its ability to estimate the dynamic relationship between variables using the lag structure of the dependent and explanatory variables, and its ability to work with relatively small sample sizes. The analysis is carried out using several econometric techniques such as unit root test, ARDL Bounds cointegration test, long run coefficient estimation, short run Error Correction Model (ECM) and diagnostic testing. The stationarity properties of the variables are first tested by the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. These tests are carried out to establish the order of integration and to make sure that no variable is integrated more than order I (1) as required for the ARDL methodology. Once the stationarity properties of the variables are confirmed, the ARDL model is estimated using the optimal lag structure determined by the Akaike Information Criterion (AIC) and the reliability of the subsequent econometric estimations is guaranteed to avoid spurious regression results. The choice of the optimal lags is crucial because it reflects the process of dynamic adjustment between variables, while at the same time reducing information loss. The ARDL Bounds Testing approach is then applied to test for the presence of a long run equilibrium relationship between economic growth, carbon dioxide emissions, industrial growth, foreign direct investment and population growth. The computed F-statistic is compared with the critical bounds values to see if cointegration exists between the variables. If cointegration is found, long-run and short-run dynamics are estimated using the ARDL Error Correction Model (ECM). The long-run estimates reflect the long-term impacts of CO_2 emissions, industrial expansion, foreign investment, and population growth on economic growth, while the short-run coefficients represent the short-term adjustments and immediate responses between the variables. The error correction term is used to calculate the rate of adjustment from short run disequilibrium to long run equilibrium. If the error correction coefficient is negative and statistically significant, then there is long run convergence. Several diagnostic tests are performed to assess the reliability of the estimated model, such as the Breusch-Godfrey Serial Correlation LM test, Breusch-Pagan-Godfrey Heteroskedasticity test, Jarque-Bera normality test and Ramsey RESET specification test. These tests are used to make sure that the estimated model has no autocorrelation, heteroskedasticity, non-normal distribution of residuals, or misspecification of the functional form. In addition, the stability of the model is evaluated by the CUSUM and CUSUMSQ tests to ensure the stability of the estimated parameters over the period of study and detect the possible structural instability. The economic growth (GDP) is the dependent variable, and carbon dioxide emissions, industrial growth, foreign direct investment, and population growth are the explanatory variables in the empirical model. The functional relationship between economic growth and the selected explanatory variables is expressed as:



The coefficient β1 reflects the effect of CO2 emissions on economic growth, β2 reflects the effect of industrial growth on economic growth, β3 reflects the effect of foreign direct investment on economic performance, and β4 reflects the effect of population growth on economic growth. The sign of these coefficients indicate the direction of the relationship between the explanatory variables and economic growth, positive or negative. In summary, this methodological approach is a comprehensive econometric analysis of the factors affecting economic growth in Pakistan. The ARDL approach combines short-run and long-run analysis, allowing for a more comprehensive understanding of how economic performance varies over time in response to changes in the environment, industrial development, foreign investment, and demographic changes. The results offer empirical evidence for policy makers in developing strategies for sustainable economic growth, industrial development, attracting investments, and environmentally balanced economic policies.

Variables	**Abbreviation**	**Operational Definitions**	**Measurement**	**Sources**
Gross Domestic Product	GDP	Gross Domestic Product (GDP) represents the total monetary value of all final goods and services produced within Pakistan during a given year. It serves as the dependent variable and is used as an indicator of the country's overall economic growth.	Current US$	World Development Indicators (WDI), World Bank
Carbon Dioxide Emissions	CO_2	Carbon dioxide (CO_2) emissions refer to the total amount of carbon dioxide released into the atmosphere from the combustion of fossil fuels and industrial processes. This variable is used to assess the environmental impact associated with economic activities.	Total CO_2 emissions (kilotons)	World Development Indicators (WDI), World Bank
Foreign Direct Investment	FDI	Foreign Direct Investment represents net inflows of investment made by foreign entities to acquire a lasting management interest in enterprises operating in Pakistan. It reflects the contribution of foreign capital to economic growth.	Net inflows (% of GDP)	World Development Indicators (WDI), World Bank
Industrial Growth	ING	Industrial Growth refers to the value added generated by the industrial sector, including manufacturing, mining, construction, electricity, gas, and water supply. It measures the contribution of industrial activities to the national economy.	Current US$	World Development Indicators (WDI), World Bank
Population Growth	PG	Population Growth measures the annual percentage increase in Pakistan's total population. It captures demographic changes that may influence labor supply, production capacity, and overall economic growth.	Annual population growth (%)	World Development Indicators (WDI), World Bank

ADF Unit Root Test

Variables	**At Level 1st P Values**	**At 1st Difference P Values**	**Integration Order**
Carbon Dioxide Emissions	0.9470	0.0000	1st Difference
Foreign Direct Investment	0.0276	0.0001	1st Difference
Gross Domestic Product	0.9989	0.0193	1st Difference
Industrial Growth	0.1437	0.0000	1st Difference
Populating Growth	0.8326	0.0032	1st Difference

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The unit root test is performed to check the stationarity characteristics of the variables involved in the study. The stationarity is a necessary condition for time-series econometric analysis because non-stationary variables can lead to incorrect regression results. The null hypothesis of the unit root test is that the variable has a unit root and is non-stationary, and the alternative hypothesis is that the variable is stationary. From the results presented in the table, it can be seen that all the variables selected are non-stationary at their level form except Foreign Direct Investment (FDI). The p-values for the variables Carbon dioxide emissions (CO_2), Gross Domestic Product (GDP), Industrial Growth (IG), and Population Growth (POP) are 0.9470, 0.9989, 0.1437 and 0.8326, respectively, which are high and do not allow us to reject the null hypothesis of a unit root. Therefore, these variables contain a stochastic trend and are not stationary at level. But, once the first difference is taken all variables are stationary as their p-values are statistically significant at the conventional 5% level. With a p-value of 0.0000, 0.0001, 0.0193, 0.0000 and 0.0032 respectively, CO2 emissions, FDI, GDP, Industrial Growth and Population Growth become stationary. All variables are found to be stationary after first differencing, which is confirmed by these results. The results show that all variables are of order one, which are denoted as I (1). This implies that one differencing operation is needed for each variable to eliminate the non-stationary trends and to obtain a stable mean and variance over time. All the variables are integrated at the same order, thus the data set meets the stationarity requirement for further time-series analysis. The presence of I(1) variables allows for the use of cointegration techniques, including the Autoregressive Distributed Lag (ARDL) model, to study both short-run and long-run relationships between carbon dioxide emissions, foreign direct investment, economic growth, industrial growth and population growth.

ARDL Model

Variables	Coefficients	T-Statistics	P-Values
GDP(-1)	0.576	4.345	0.0001
GDP(-2)	0.409	3.000	0.0049
CO_2	0.10	0.489	0.6278
CO_2(-1)	0.20	0.683	0.4992
CO_2(-2)	0.22	0.613	0.5436
CO_2(-3)	-1.62	-3.810	0.0005
CO_2(-4)	1.16	3.858	0.0005
FDI	-2.68	-0.546	0.5883
FDI(-1)	15.20	2.076	0.0451
FDI(-2)	-11.10	-1.523	0.1364
FDI(-3)	-4.59	-0.667	0.5091
FDI(-4)	13.90	2.564	0.0147
IG	1.78	3.760	0.0006
POP	-6.45	-1.291	0.2049
Constant	7.90	0.449	0.6561

The Short Run dynamic relationship between Gross Domestic Product (GDP) as the dependent variable and its determinants, Carbon Dioxide Emissions (CO_2), Foreign Direct Investment (FDI), Industrial Growth (IG) and Population Growth (POP) are examined in the ARDL estimation results. The statistical significance of each variable is tested using t-statistics and p-values, with p-values < 0.05 considered significant for its impact on economic growth. The lagged GDP has a significant and positive impact on the current economic growth. The coefficient of GDP (-1) is 0.576, t-statistic is 4.345, and the p-value is 0.0001, which shows that there is a statistically significant positive relationship. This indicates that the economic activity of the past is important for the current GDP growth, implying persistence and continuity in economic activity. Likewise, GDP(-2) has a positive coefficient of 0.409, a t-statistic of 3.000 and a p-value of 0.0049, indicating that GDP growth in the second previous period also has a positive impact on current economic growth. The results suggest that economic growth is a dynamic process in which the level of economic activity in the past is important for the current level of economic activity. The findings indicate that CO_2 emissions have mixed impacts on economic growth for various lags. The contemporaneous CO_2 emissions has a positive coefficient (0.10) but is not statistically significant ($p = 0.6278$) suggesting that current CO_2 emissions have no significant immediate effect on GDP. Likewise, the coefficient values for CO_2 (-1) and CO_2 (-2) are positive, but not statistically significant (p-values of 0.4992 and 0.5436, respectively). This means that the short-term effects of past carbon emissions on economic growth are not statistically significant. The coefficient of CO_2 (-3) is -1.62, the t-statistic is -3.810, and the p-value is 0.0005, which is negative and statistically significant with respect to GDP. This suggests that the more carbon emissions increase in the three periods, the lower the economic growth, which may be because of environmental damage, health expenses, loss of productivity, and inefficiency in resource use. On the other hand, CO_2 (-4) has a positive and significant coefficient of 1.16, t-statistic of 3.858 and a p-value of 0.0005. This indicates that carbon-based economic activities could have a positive impact on growth after four periods, which is indicative of the positive impact of energy use and industrial production on economic growth. The overall results suggest nonlinear as well as delayed relationship between environmental pressure and economic growth. The coefficient of current FDI is negative (-2.68) but not statistically significant ($p = 0.5883$), suggesting that the short-run impact of current foreign investment inflows on GDP is not significant. The coefficient of FDI (-1) is 15.20, t-statistic is 2.076, and the p-value is 0.0451 which is positive and statistically significant and has a positive sign. This means that foreign investment is beneficial to the economy in the first period. The finding indicates that the positive effects of FDI might be delayed in the form of technology transfer, accumulation of capital, job creation and productivity gains. The second and third lags of FDI (FDI (-2) and FDI (-3)) are not statistically significant at the 5% level with p-values of 0.1364 and 0.5091 respectively. The coefficient of FDI (-4) is 13.90, the t-statistic is 2.564 and the p-value is 0.0147, indicating that FDI (-4) is significant and positive. This means that the long-term impacts of foreign investment are beneficial to economic growth, as it increases productive capacity and boosts economic activities. Growth of industries has a positive and significant relationship with GDP. The coefficient of IG is 1.78, t-statistic is 3.760 and p-value is 0.0006, which means that industrial expansion has a significant effect on economic growth. This discovery underscores the significance of industrial development in improving the economic performance by enhancing production, employment creation, infrastructure development, and economic productivity. The findings confirm the hypothesis that industrialization continues to be a key factor in economic development in developing countries. Population growth is statistically insignificant with a coefficient of -6.45 and a t-statistic of -1.291 and a p-value of 0.2049. This means that in the short run, population growth is not important for GDP. The negative aspect indicates that the population growth rate could lead to economic pressures, such as resource scarcity, job shortages, and strain on public services. The insignificant result, however, suggests that population growth alone does not have a significant impact on economic growth without an increase in human capital, employment opportunities, and productivity. The constant coefficient is positive (7.90) but not statistically significant ($p = 0.6561$), meaning that the intercept does not have an independent significant effect on GDP when the other explanatory variables are taken into account.

Model Summary

Statistics	Values
Selected Model	ARDL(2, 4, 4, 0, 0)
Observations	51
R^2	0.996
Adjusted R^2	0.994
F-statistic	637.962

Prob. (F-statistic)	< 0.001
Durbin–Watson Statistic	2.018
Akaike Information Criterion (AIC)	48.945
Schwarz Criterion (SC)	49.513

The ARDL model summary shows the overall goodness of fit, explanatory power and diagnostic indicators of the estimated model ARDL (2, 4, 4, 0, 0). The model examines the relationship between Gross Domestic Product (GDP) and its explanatory variables such as Carbon Dioxide Emissions (CO_2), Foreign Direct Investment (FDI), Industrial Growth (IG) and Population Growth (POP). Model Specification and Observations; The selected model is ARDL(2, 4, 4, 0, 0), which means that the model contains two lags of GDP, four lags of CO_2 emissions, four lags of FDI and no lag for Industrial Growth and Population Growth. There are 51 observations, enough for time-series analysis. The goodness of fit (R^2 and Adjusted R^2) is 0.996, which means that around 99.6% of the variations in GDP are explained by the explanatory variables and their lagged values included in the model. This indicates that the ARDL model has a very high explanatory power. The adjusted R^2 value of 0.994 also indicates that the model has a high explanatory power even when adjusted for the number of explanatory variables and the complexity of the model. This indicates that the variables chosen are able to give a significant amount of information to explain the changes in economic growth. Overall Significance of the Model (F-statistic): The model has an F-statistic value of 637.962 with a probability value of less than 0.001, which means that the overall regression model is statistically significant at the 1% significance level. This outcome is contrary to the null hypothesis that all of the explanatory variables together have no effect on GDP. Thus, the total of CO_2 emissions, FDI, industrial growth, population growth and lagged effects account for substantial differences in economic growth. Durbin–Watson Statistic: Durbin–Watson statistic is 2.018, very close to the ideal value of 2. This means that there are no serious autocorrelation problems in the residuals of the model. A value close to 2 indicates that the error terms are not correlated over time, which is a good sign of the reliability and efficiency of the estimated ARDL coefficients. Information Criteria (AIC and SC): AIC = 48.945, SC = 49.513. The following criteria are used to assess model selection, where goodness of fit and model complexity are balanced. The lower values mean that the model specification is more efficient. These information criteria were used to select the ARDL model which indicates that the selected model is appropriate with respect to the explanatory power and avoiding unnecessary lags.

ARDL Long Run & Bounds Cointegration

Variables	**Coefficients**	**T-Statistics**	**P-Values**
CO2	3.38	0.503	0.618
FDI	689.47	0.266	0.792
IG	113.35	0.286	0.777
POP	-410.60	-0.290	0.774
Constant	502.62	0.246	0.807

Variable	Coefficients	T-Statistics	P-Values
ΔGDP(-1)	-0.409	-3.000	0.005

Test Statistics	Values	5% Lower Bound I(0)	5% Upper Bound I(1)	Decision
F-Statistics	7.934	2.823	3.872	Cointegration Exists

The ARDL long-run estimation results are used to investigate the long-run relationship between Gross Domestic Product (GDP) and its explanatory variables: Carbon Dioxide Emissions (CO_2), Foreign Direct Investment (FDI), Industrial Growth (IG), and Population Growth (POP). The long run coefficients show the direction and strength of the relationship, and the t statistics and p values show the statistical significance of each variable. The long run coefficient of Carbon Dioxide Emissions (CO_2) is 3.38, t-statistic is 0.503 and p-value is 0.618. The positive coefficient suggests that in the long run, CO_2 emissions are positively related to economic growth. This implies that GDP growth can be linked to higher carbon emissions, which are typically linked to higher energy use, industrial production and economic activities. The relationship is not statistically significant, however, due to the p-value being higher than the 5% significance level. Hence, the long-run effects of CO_2 emissions on economic growth are not statistically significant. The coefficient of Foreign Direct Investment (FDI) is positive and long run, t-statistic is 0.266 and p-value is 0.792. The positive sign indicates that FDI is a positive contributor to economic growth in the long term. This means that foreign investment can contribute to economic performance in terms of capital accumulation, technology transfer, job creation and productivity gains. The relationship is however, statistically insignificant, suggesting that FDI does not have a significant long run impact on GDP during the study period. The long-run coefficient for Industrial Growth (IG) is 113.35, the t-statistic is 0.286, and the p-value is 0.777. The positive coefficient means that industrial development is conducive to economic growth by expanding production capacity, creating jobs and enhancing economic activities. However, the high p-value shows that the effect is not statistically significant, which means that industrial growth does not have a significant long-run impact on GDP in the estimated model. The coefficient for Population Growth (POP) is -410.60, the t-statistic is -0.290, and the p-value is 0.774. The negative sign indicates that population growth may negatively affect economic growth in the long run. Rapid population growth may put strain on natural resources, jobs, infrastructure and public services. The relationship is statistically insignificant, however, which means that population growth has no significant long run effect on GDP. The constant term is 502.62 with a t-statistic of 0.246 and a p-value of 0.807. The coefficient is positive, but not statistically significant, meaning that the constant term does not account for any of the variation in GDP when the other variables in the model are included. Error Correction Term (Short-Run Adjustment). The error correction coefficient, ΔGDP (-1), is statistically significant with a negative coefficient of -0.409, a t-statistic of -3.000 and a p-value of 0.005. The negative sign indicates that there is an adjustment mechanism from short run disequilibrium to long run equilibrium. The coefficient suggests that about 40.9% of the deviations from the long-run equilibrium are corrected in one period. In other words, the economy responds slowly to short-term shocks to GDP, moving back to the long-run path of equilibrium. ARDL Bounds Test for Cointegration. The ARDL Bounds test is used to check the presence of a long-run equilibrium relationship between the variables. The calculated F-statistic is 7.934 and is compared with the critical values at 5% significance level. The lower bound I(0) value is 2.823, while the upper bound I(1) value is 3.872. The calculated F-statistic (7.934) exceeds the upper bound critical value I(1) (3.872), which means that the null hypothesis of no cointegration is rejected. Thus, the findings support the presence of cointegration between GDP, CO_2 emissions, FDI, industrial growth and population growth. This means that the variables change in the long run, even though there are short-term changes. The ARDL long-run results show that the relationship of CO_2 emissions, foreign direct investment and industrial growth with economic growth is positive in long run while the relationship of population growth with economic growth is negative in long run. But none of the individual long run coefficients are statistically significant. The large and negative error correction term is a confirmation of a stable adjustment process to long-run equilibrium. In addition, the Bounds test result shows that the variables are in a long run cointegrating relationship since the value of the F-statistic (7.934) is greater than the upper bound critical value (3.872). Hence, the ARDL model is suitable for studying the short-run dynamics and long-run relationship between economic growth and its environmental and socioeconomic determinants.

ARDL Short Run

Variable	Coefficients	T-Statistics	P-values
ΔGDP(-1)	-0.409	-3.602	0.001
ΔCO_2	0.10	—	0.000

$\Delta CO_2(-1)$	0.25	—	0.000
$\Delta CO_2(-2)$	0.46	—	0.000
$\Delta CO_2(-3)$	-1.16	—	0.000
ΔFDI	-2.68	—	0.000
ΔFDI(-1)	1.71	—	0.000
ΔFDI(-2)	-9.36	—	0.000
ΔFDI(-3)	-13.90	—	0.000
ECT(-1)	-0.016	-7.363	0.001

Statistics	**Values**
Selected Model	ARDL(2, 4, 4, 0, 0)
Observations	51
R^2	0.755
Adjusted R^2	0.701
Durbin–Watson Statistic	2.018

The ARDL short run estimation results provide the immediate dynamic impact of the changes in Gross Domestic Product (GDP), Carbon Dioxide Emissions (CO_2) and Foreign Direct Investment (FDI) on economic growth. The estimated model is ARDL (2, 4, 4, 0, 0), based on 51 observations. The short-run coefficients show the effect of short-run changes in the explanatory variables on GDP, prior to the return to the long-run equilibrium. The coefficient of the lagged GDP, ΔGDP (-1), is statistically significant and negative (-0.409) with a t-statistic of -3.602 and a p-value of 0.001. The negative sign means that economic growth changes in the past have an adjustment effect on the current growth of GDP. This implies that GDP is corrected for short-term fluctuations over time, which is characteristic of economic growth. The statistical significance establishes that the changes in GDP in the past have been important in explaining the current economic performance. The short-term impacts of Carbon Dioxide Emissions (CO_2) show mixed but notable impacts on economic growth. The current change of CO_2 emissions (ΔCO_2) has a positive coefficient of 0.10 and a p-value of 0.000, which means that an increase in carbon emissions in the short run has a positive impact on GDP. This implies that the energy consumption, industrial production and economic activities that generate carbon emissions are responsible for short-term economic growth. The coefficient of the first lag of CO_2 emissions, ΔCO_2 (-1) is positive and statistically significant at 0.25 ($p = 0.000$). This means the positive impact of carbon-intensive activities is sustained over a period of time. Likewise, the coefficient of $\Delta CO_2(-2)$ is positive with a significant p-value of 0.000, indicating that the increase in energy use and industrial activities still play a positive role in the short-run economic growth. The coefficient of ΔCO_2 (-3) is, however, negative (-1.16) and statistically significant ($p = 0.000$). This means that, after three periods, an increase in carbon emissions starts to have a negative impact on economic growth. The negative impact can relate to environmental degradation, increased health-related costs, decreased productivity and inefficient use of resources. The findings suggest that the CO_2 emissions–economic growth nexus is dynamic, as emissions can boost the economy in the short term but have negative impacts in the long term. The effect of Foreign Direct Investment (FDI) is also different in different time periods in the short run. The current change in FDI (ΔFDI) has a negative coefficient of -2.68 and is statistically significant ($p = 0.000$). This means that foreign investment inflows can have a negative impact on GDP in the short run. This may be because foreign investments can take time to be implemented, infrastructure built up and productivity improved before the economic benefits can be felt. The coefficient of the first lag of FDI, ΔFDI (-1), is positive and statistically significant ($p = 0.000$). This implies that the positive effects of foreign investment are realized after a period of delay, for example, via capital accumulation, technology transfer, job creation, and production efficiency. On the other hand, the coefficient of ΔFDI (-2) and ΔFDI (-3) are negative and statistically significant, at -9.36 and -13.90, respectively. The findings suggest that the effect of FDI is not constant in time and varies with the type of FDI, the economic environment and the ability of domestic institutions to make good use of foreign capital.

The error correction term (ECT (-1)) is statistically significant with a negative coefficient of -0.016 and t-statistic of -7.363 and a p-value of <0.001. The negative sign indicates that a valid adjustment mechanism towards long-run equilibrium exists. The coefficient means that about 1.6% of the short-run deviations from the long-run equilibrium are corrected in every period. The adjustment speed is relatively slow, but the important ECT indicates that the variables are in a stable long-run relationship. The model estimated by ARDL (2, 4, 4, 0, 0) is based on 51 observations. The R^2 value is 0.755, which means that the model explains about 75.5% of the variation in GDP. The adjusted R^2 value of 0.701 is not significantly lower than the value of 0.835, which indicates that the model still has a good explanatory power despite the number of predictors. The Durbin–Watson statistic is 2.018, close to the optimum value of 2. This means that there are no serious autocorrelation problems with the model, and that the residuals are not correlated from one period to the next. Hence, the short-run coefficients are estimated to be reliable. The short-run ARDL results show that GDP dynamics, CO_2 emissions, and FDI have a significant impact on the short-run economic growth. The initial effect of CO2 emissions is positive on GDP, as energy consumption and industrial activities contribute to economic production. The negative impact of CO_2 after three periods, however, indicates that in the long run, high environmental pressure can have a negative impact on economic growth. Foreign Direct Investment has mixed short-run effects, negative in the short run and positive and negative in the long run, suggesting that the economic benefits of foreign investment are dependent on timing and the efficiency of the investment. The large and negative error correction term indicates that the short run deviations are corrected toward the long run equilibrium. In conclusion, the ARDL model is appropriate for analyzing the short-run dynamics and long-run relationship between economic growth, environmental factors, foreign investment and structural economic variables.

Breusch–Godfrey Serial Correlation LM Test

Test Statistics	**Values**	**P-Values**
F-statistics	0.218	0.806
Obs*R-squared (Chi-square)	0.645	0.724

To check for the presence of serial correlation (autocorrelation) in the residuals of the estimated ARDL model, the Breusch–Godfrey Serial Correlation LM test was used. The test's null hypothesis is that there is no serial correlation among the error terms, while the alternative hypothesis is that there is serial correlation among the error terms. The results indicate that the value of F-statistic is 0.218 and the p-value is 0.806, which is much greater than the 5% level of significance. Thus, the null hypothesis that there is no serial correlation is not rejected. In the same way, the Obs*R-squared (Chi-square) statistic is 0.645 with a p-value of 0.724, which also indicates that there is no autocorrelation in the residuals. The results show that the estimated ARDL model is free from the problem of serial correlation, that is, the residuals are uncorrelated over time. The absence of serial correlation helps to establish the validity of the estimated parameters and the validity of the statistical inferences such as hypothesis testing and interpretation of the coefficients. Thus, the ARDL model is a diagnostic model that meets the assumption of error independence.

Breusch–Pagan–Godfrey Heteroskedasticity Test

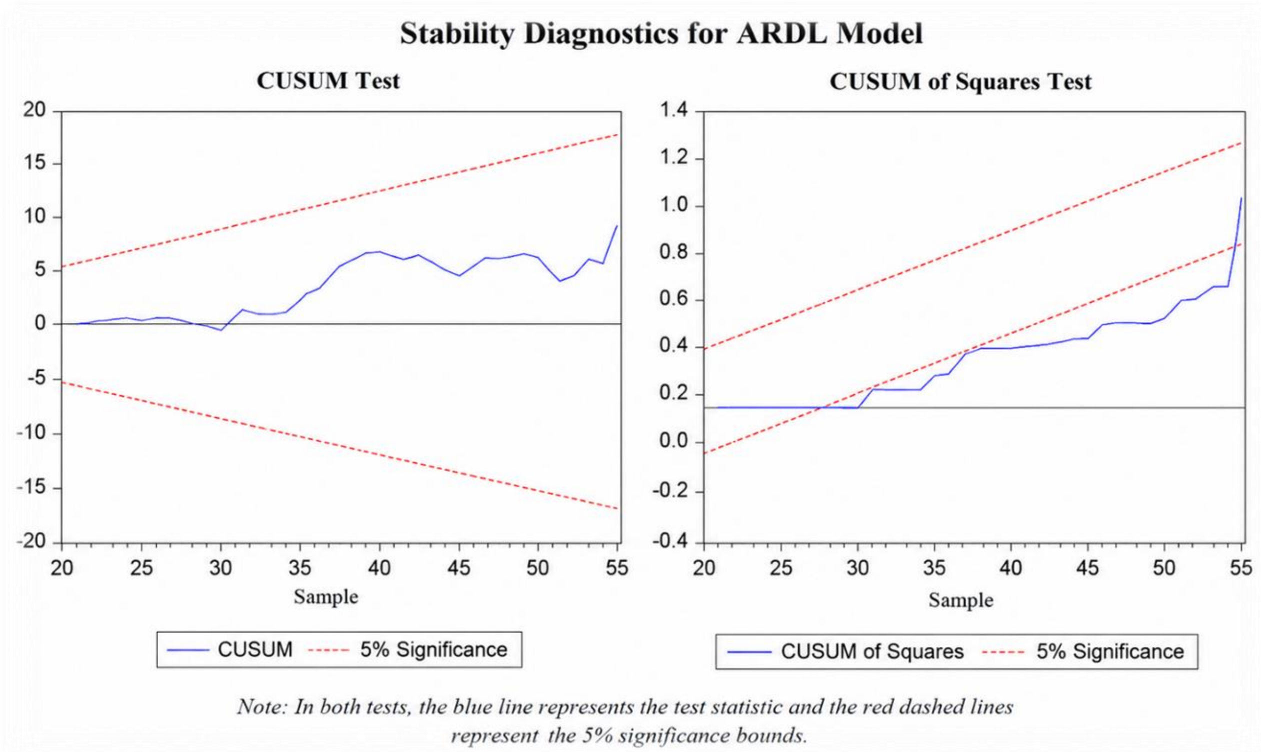
Test Statistic	**Values**	**P-Values**
F-statistic	1.751	0.088
Obs*R-squared (Chi-square)	20.661	0.111
Scaled Explained SS	13.521	0.486

The Breusch–Pagan–Godfrey heteroskedasticity test is used to check the homoskedasticity of the estimated ARDL model. This test is used to test the null hypothesis that the model is homoscedastic (error terms have constant variance) against the alternative hypothesis that the model is heteroscedastic (error terms have varying variance). The value of the F statistic is 1.751 and the p value is 0.088. Since the p-value is greater than the 5% significance level, the null hypothesis of homoscedasticity cannot be rejected. This means that there is not a great deal of heteroskedasticity in the model. Likewise, the Obs*R-squared (Chi-square) value is 20.661 and the p-value is 0.111. The small p-value indicates that the residual variance is constant through time. In addition, the Scaled Explained SS value is 13.521 and the p-value is 0.486, which also indicates that there is no heteroskedasticity in the model. The overall test result of Breusch–Pagan–Godfrey test indicates that the estimated ARDL model fulfills the assumption of constant error variance. Thus, the regression coefficients and statistical inferences are reliable and efficient.

Ramsey RESET Test

Test Statistics	Values	P-Values
T-Statistics	1.981	0.056
F-Statistics	3.924	0.056

The Ramsey Regression Equation Specification Error Test (RESET) is performed to check the specification errors in the ARDL model, including omitted variables, wrong functional form, and inappropriate model structure. The null hypothesis of the Ramsey RESET test is that the model is correctly specified and the alternative hypothesis is that the model is mis-specified. The test result is t-statistic value is 1.981 and p-value is 0.056, F-statistic value is 3.924 and p-value is 0.056. Both p-values are slightly higher than the 5% significance level, meaning that the null hypothesis of correct model specification cannot be rejected. The results indicate that the ARDL model is well specified and there are no significant functional form issues or omitted variable bias. The p-value is near the 5% significance level, but not quite, suggesting that the model specification is satisfactory. The results of the diagnostic test support the reliability and stability of the ARDL model. All reported p-values are greater than 5% and the Breusch–Pagan–Godfrey test suggests that there is no evidence of heteroskedasticity. The Ramsey RESET test also provides further evidence of the correct specification of the model, as there is no significant evidence of misspecification. Hence, the estimated ARDL model is a statistically sound model for studying the relationship between economic growth, CO_2 emissions, foreign direct investment, industrial growth, and population growth.



CUMSUM Test

The CUSUM test is used to examine the stability of the estimated coefficients over the sample period. The null hypothesis is that the parameters of the model do not change during the study period. The blue CUSUM line stays in the two red dashed 5% significance lines for the entire sample period. The CUSUM line does not cross or touch the critical bounds. The CUSUM statistic indicates a slowly increasing trend towards the end of the sample but is still well within the CUSUM limits. The CUSUM test shows that the estimated ARDL model is structurally stable at 5% significance level. The CUSUM statistic is not outside the critical range, so the null hypothesis of parameter stability is not rejected. This implies that the estimated coefficients are constant throughout the study period, and that there were no evidence of structural instability or structural breaks in the model. Hence, the long-run and short-run estimates derived from ARDL model are reliable and appropriate for policy analysis and forecasting.

Diagnostic Tests	**Results**	**Conclusion**
Jarque–Bera Normality Test	$p = 0.1055$	Residuals are normally distributed
Breusch–Godfrey LM Test	$p = 0.724$	No serial correlation
Breusch–Pagan–Godfrey Test	$p = 0.111$	No heteroskedasticity
Ramsey RESET Test	$p \approx 0.056$	Functional form is acceptable at the 5% level
CUSUM Test	Within 5% bounds	Coefficients are stable
CUSUM of Squares Test	Within 5% bounds	Variance and model stability confirmed

CONCLUSION

The purpose of this study was to investigate the relationship between economic growth, carbon dioxide (CO_2) emissions, industrialization, foreign direct investment (FDI) and population growth in Pakistan for the period 1970-2025. The ARDL bounds testing approach was used due to the mixed order of integration of the variables, which makes the ARDL framework suitable for estimating both short-run and long-run relationships. The empirical analysis verified the existence of a long run equilibrium relationship between the study variables. Furthermore, the estimated ARDL model was able to explain the long run and short run dynamics affecting the economic growth of Pakistan. In addition, the diagnostic tests showed that the estimated model is statistically valid and reliable. The Jarque–Bera test showed that the residuals are normally distributed and the Breusch–Godfrey LM test showed no serial correlation. Similarly, the Breusch–Pagan–Godfrey test showed that the residuals are homoscedastic, and the Ramsey RESET test suggested that the model is correctly specified. Furthermore, the CUSUM and CUSUMS tests showed that the parameters were stable over the study period, suggesting that the estimated coefficients were stable and that there was no significant structural instability in the model. The results indicate that the economic growth of Pakistan is affected by environmental, demographic and investment factors. Industrialization and foreign direct investment are important factors in increasing productive capacity and in fostering economic development, and population growth affects the availability of labor and market size. Meanwhile, the increase in CO_2 emissions serves as a reminder of the environmental impact of economic growth and industrial processes, underscoring the importance of adopting sustainable development strategies. In addition, policymakers should develop comprehensive policies that encourage both economic growth and environmental sustainability based on these results. More attention should be given to promoting environmentally friendly industrialization, promoting green FDI, improving energy efficiency, increasing renewable energy resources, and enhancing environmental regulations. Furthermore, human capital, technology and sustainable infrastructure investments should be made a priority to ensure long-term economic success without sacrificing environmental quality. In general, this study is a valuable addition to the existing literature on sustainable economic development in Pakistan, as it offers fresh empirical findings based on the latest data and a comprehensive ARDL framework. In last, the findings offer such valuable a set of insights for policymakers seeking to balance economic growth with environmental sustainability and support the achievement of sustainable development objectives.

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