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Economic Growth, Industrialization, and CO2 Emissions in Pakistan: Insights from ARDL Modeling

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ABSTRACT

This study explores how industrialization, economic growth (measured by GDP per capita), and CO_2 emissions have interacted in Pakistan over nearly five decades, from 1974 to 2022. It also considers the influence of population growth and foreign direct investment (FDI) on this relationship. To analyze the data, the ARDL model was used, ensuring the reliability of the results by confirming stationarity with the Augmented Dickey-Fuller (ADF) test. The results showed that in the long run, a 1% increase in GDP per capita and FDI inflows results in respective increases in CO_2 emissions of 0.33% and 0.061%. Still, a 1% rise in industrial activity lowers CO_2 emissions by 0.34%. In the short run, a 1% rise in GDP per capita and FDI reduces CO_2 emissions by 0.21% and 0.020%, respectively. Conversely, a 1% increase in industrial activity causes emissions of 0.29%. These findings are in line with the Environmental Kuznets Curve (EKC) theory, which holds that CO_2 emissions initially rises when a nation industrializes but as the technology advances and more rigorous rules are followed, the level of CO_2 emissions decreases. Based on these results, policies emphasizing investments in renewable energy, strict environmental rules enforced, and support of clean technologies and sustainable industrial practices are suggested.

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1. Introduction

Determining how to have economic development without harming the environment presents a difficult task for Pakistan and many other emerging economies. While the economies of emerging nations have grown as they have modernized and progressed, pollution levels are also rising. The increasing levels of CO2 emissions, which have a detrimental impact on the climate, are one of the most significant concerns for developing countries. Studies have indicated that in the early stages of industrialization, human development may increase CO_2 emissions, even when technological innovations are present (Yang, Shafiq, Sharif, Gillani, & Zeng, 2024). Similarly, research on China's transformation highlights that while technological innovation can mitigate environmental degradation caused by energy consumption, factors like economic growth and industrial structure are still positively associated with CO_2 emissions (Yang, Shafiq, Nazir, & Gillani, 2024).

The economy of Pakistan has experienced a significant growth since 1974. The manufacturing and construction sectors are the two most notable sectors that have experienced significant growth. This sectoral growth has resulted in poverty alleviation and improvement of the living standard of people. This economic growth has also resulted in the increased level of CO2 emissions in the environment. Pakistan's CO_2 emissions have been increased by development, economic growth, and other factors like population growth, foreign investment, and economic growth (Nawaz, Azam, & Bhatti, 2019). We can find the best way to balance economic growth with natural sustainability if we understand these connections. The goal is to find ways for Pakistan to keep its economy growing while also keeping the C02 emissions at check.

A vast area of economic study for many years has been how industrialization, economic growth, and environmental sustainability affect each other. Industrialization has an adverse effect on the environment, especially higher CO_2 emissions that make it hard for countries to grow their economies while keeping their environment clean. Pakistan has undergone numerous economic reforms and industrialization initiatives, with a population exceeding 220 million. Pakistan's manufacturing sector is of significant economic significance; as of 2023, it employed approximately 24% of the workforce and contributed approximately 20% to the country's GDP. Over the past few decades, Pakistan's industrial output has experienced substantial growth.

From 1974 to 2022, the country's industrial value added grew at an average rate of 5.5% per year. The fast growth of industry has caused a sizable increase in CO_2 pollution, which makes people worry about the country's ability to continue growing. Pakistan's CO2 emissions per capita went from 0.34 metric tons in 1974 to 1.05 metric tons in 2022. This is because the country's nonrenewable energy-based economy became more industrialized and needed more energy. The country has mostly used oil and natural gas for energy, with green energy sources making up only a small part of the total. In 2021, fossil fuels made up almost 84% of Pakistan's main energy source. This made the country's carbon footprint bigger.

CO2 emissions per person are likely to change drastically because of how quickly industrial growth is taking place. This trend is primarily caused by the fact that many industrial activities depend on fossil fuels, which cause more CO2 to be released into the air. This problem is made even worse by the fact that developing countries don't have strict environmental laws. The Environmental Kuznets Curve (EKC), on the other hand, shows that emissions go up in the initial stages of industrialization but go down as countries get older and use tighter environmental laws and better technologies. The point of this study is to test this idea in Pakistan and see how industry value added affects CO2 emissions per person by looking at time series data.

Pakistan's GDP per person has grown immensely from $278 in 1974 to $1537 in 2022 (in constant 2010 US dollars). Even though economic growth has reduced poverty and raised living standards, it has also increased energy use and CO_2 emissions (Nawaz, Ahmad, Hussain, & Bhatti, 2020). This shows that economic success has environmental costs. There is a complicated link between GDP per capita and CO_2 emissions per capita. This is because higher GDP can lead to higher emissions because people use more energy. But the EKC theory says that as countries grow, CO_2 emissions may go down because of tighter rules, better technologies, and more people caring about the environment. This research looks at whether this theory is true for Pakistan and how the country's economic growth affects its CO2 emissions path.

This study's core purpose is to delve into the interaction between Pakistan's industrialization, GDP per capita, and CO_2 emissions per capita (Bhatti & Fazal, 2020). The relevant research inquiries are: (i) How has industrialization affected Pakistan's per-capita CO_2 emissions? (ii) How do CO2 emissions per capita and GDP per capita relate to one another? (iii) Considering both population growth and FDI inflows as control variables, what effect do they have on per capita CO2 emissions?

2. Literature Review

The interaction amidst economic growth and environmental pollution has garnered significant interest among researchers, policymakers, and practitioners worldwide. While economic growth theoretically should lead to environmental benefits, this assumption does not always hold true in practice. The impact of growth rates, industrialization, and foreign direct investment on carbon emissions has been the subject of several studies, many of which have focused on Pakistan.

According to Hussain, Irfan Javaid, and Drake (2012) CO2 emissions per capita in Pakistan climb linearly with GDP per capita. The ARDL technique, which is popular for studying time series data, shows that industrialization and growth rate have a positive impact on CO2 emissions in Pakistan. Granger causality tests supported the findings of Mirza and Kanwal (2017), who discovered a bidirectional causal connection between energy usage, economic development, and CO2 emissions in both the short and long term. The most popular technique for doing research with time series data is the ARDL approach. The study's conclusions show that Pakistan's industrialization and development rate have a favorable effect on CO2 emissions.

Furthermore, Khan, Khan, and Rehan (2020) also showed that Pakistan's CO2 emissions, economic growth, and energy use are all linked in a good way over the long run. The real-world results show that while population and CO2 emissions are good for economic growth in the short term, industry value-added and energy usage are much better for economic growth in the long term (Abbasi, Shahbaz, Jiao, & Tufail, 2021). According to Wang, Gillani, Balsalobre-Lorente, Shafiq, and Khan (2024) CO2 emissions negatively effects the mortality rates. On the other hand, Wang, Gillani, Razzaq, et al. (2024) studied that long-term environmental degradation is detrimental to SWB.

Khan, Teng, Khan, and Khan (2019) say that goods trade, foreign direct investment, energy use, and economic development all have positive effects on short-term CO2 emissions. Urbanization, economic growth, and modern technologies, on the other hand, make CO2 pollution worse. Their models show that trade and foreign direct investment raise CO2 emissions in the short term. On the other hand, they say that energy use, population, economic growth, financial development, and economic globalization lower CO2 emissions (Vu et al., 2023).

Bakhsh, Rose, Ali, Ahmad, and Shahbaz (2017) observed that growth is adversely affected by pollution emissions and that greater pollution emissions are correlated with faster economic growth. As long as the capital accumulation effect is there, economic development and foreign direct investment have a large and favorable impact on capital stock. Their study also indicated that pollution rises with economic expansion, but eventually, economic growth declines when pollution levels surpass a certain threshold, showing a positive correlation between pollution and foreign direct investment. Using the ARDL bound testing approach, Ali et al. (2021) showed no significant relationship between net domestic credit and CO2 emissions, energy usage, or GDP in Pakistan.

According to Rehman, Ma, and Ozturk (2021) economic progress reduces CO2 emissions but industrialization raises them. Their long-term investigation showed that although emissions from solid fuel use had a negative correlation with economic development, those from transportation, liquid fuel, industrial activity, and fossil fuels all had positive correlations. Another study's findings showed that although economic growth has a negative effect on CO_2 emissions, industrialization has a positive effect on them.

Shafiq and Zafar (2023) have studied the link between CO_2 emissions, energy consumption and technological innovation by using the PMG-ARDL model in BRICS countries. Results indicate that technological innovation decreases CO_2 emissions while greater energy usage results in increased level of CO_2 emissions in the environment. In another study, the manufacturing sector, usage of fossil fuels and transportation results in increased level of CO_2 emissions in the long run. But in Pakistan's case carbon emissions negatively impacted its economic progress (Rehman, Ma, Ahmad, Işık, & Ozturk, 2023).

Ullah, Ozturk, Usman, Majeed, and Akhtar (2020) employed a nonlinear ARDL model considering human capital, GDP, and urbanization as potential drivers of CO_2 emissions. They found asymmetric effects of industrialization shocks on CO_2 emissions in both long and short terms, showing that deindustrialization led to a decrease in emissions while industrialization increased emissions in Pakistan.

According to the long-term regression study, the main causes of decoupling are urbanization and carbon intensity. In Pakistan, economic growth and industrialization impede the decoupling process (Khan & Majeed, 2023). There have been several studies using the VAR model. The VAR model predicts that in response to an invention that is one standard deviation outside the model, it will take around thirteen years for CO2, nineteen years for urbanization, sixteen years for industrialization, and roughly twelve years for economic growth. Two unilateral causalities were verified by the investigation: namely, that CO2 emissions and both urbanization and economic expansion are related (Parveen, Khan, & Farooq, 2019).

Industrialization causes the CO2 emissions by the activity of both middle-class and upper-class people to rise while their energy consumption falls. Conversely, urbanization has a major impact on rising energy prices and greenhouse gas emissions. It's interesting to note that industrialization was shown to have very little effect on energy usage and CO2 emissions for middle-class and upper-class individuals (Li & Lin, 2015). As the newly industrialized countries consume more energy over time, there is a corresponding increase in carbon dioxide emissions, leading to more pollution of our environment. However, when it comes to economic growth, trade openness, and urbanization, it has been seen that the environmental quality is positively correlated with these factors in the long term (Hossain, Santhanam, Nik Norulaini, & Omar, 2011).

The bootstrap ARDL bound test was used by Ghazouani (2022) to verify the cointegration of CO2 emissions and their determinants. The results demonstrated the detrimental effects of industrialization, GDP development, and rising energy use on the environment. The research detected considerable environmental advantages from coupling FDI with technical innovation, but it revealed only a weak correlation between CO2 emissions, FDI inflows, and technological development in Tunisia.

3. Data and Methodology

The time series data used in this research spans the years 1974 through 2022. The World Bank database had been employed to gather secondary data. In this study, a total of five variables are employed. The research's dependent variable is the amount of CO2 emissions per person. GDP per capita, the value generated by industrial expansion, net inflows of foreign direct investment, and population growth are the independent variables. Table 1 shows variables used in the study and the source of data. While Table 2 shows the variable employed in the study and their definition. The time trends of the variables used in the study from 1974 to 2022 reveal notable patterns. Figure 1 shows the time series trend of variables.

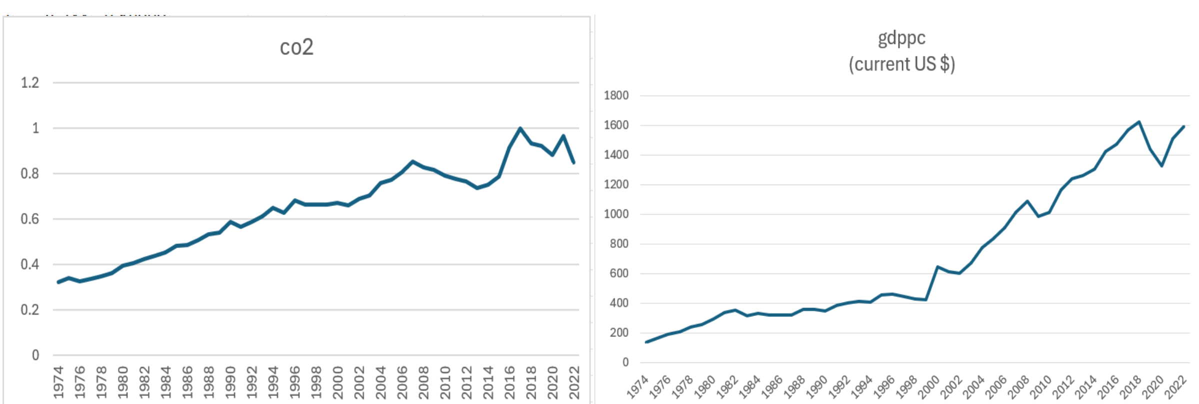
Table 1
Description of the Variables

Variable	Abbreviation	Measurement	Source
CO2 emissions	CO2	Metric tons per capita	WDI
GDP per capita	GDPPC	Current US$	WDI
Industrial growth	IND	Current US$	WDI
Foreign direct investment	FDI	Inflows (% of GDP)	WDI
Population growth	PG	Annual %	WDI

Table 2
Definitions of the Variables

CO_2 emissions	Annual CO_2 emissions per capita" measures the average carbon dioxide emitted by an individual each year.
GDP per capita	Gross Domestic Product (GDP) per capita is a crucial economic metric that quantifies the average income or output per individual in a nation. The calculation involves dividing the aggregate GDP by the population size.
Industrial growth	The "annual value added by industrial growth" measures the additional value generated by industrial activities such as manufacturing, mining, and construction in a specific year
Foreign direct investment (FDI)	Net foreign direct investment (FDI) inflows represent the net amount of foreign investments entering a country within a specific period, calculated by subtracting total FDI outflows from total FDI inflows.
Population growth	Population growth measures the alteration in the size of a population throughout a specific timeframe, usually one year. The calculation involves comparing the aggregate number of births and immigrants to the aggregate number of deaths and emigration.

Figure 1 shows the time trends of the study variables. CO_2 emissions per capita have increased over the years, with a noticeable downward trend from 2008 to 2013, followed by another decrease from 2017 to 2020. GDP per capita has risen significantly, from below $200 in 1974 to $1600 in 2022. A notable dip occurred in 2019 due to the economic impact of the COVID-19 pandemic. There has been a gradual increase in the percentage of GDP from foreign direct investments, particularly between 2000 and 2008.



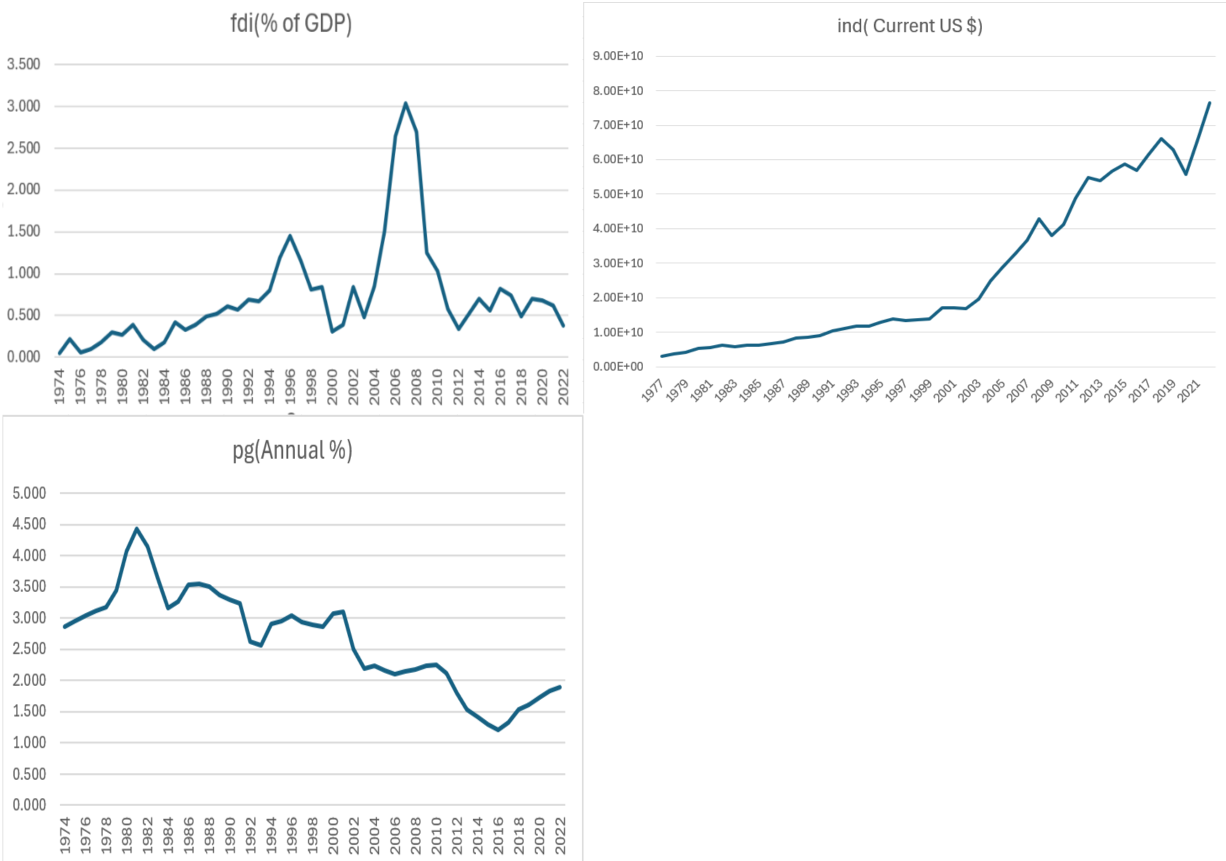


Figure 1: Trends of the Variables

During this period, Pakistan's GDP grew at an average rate of 7.5%, attracting foreign investors. Economic liberalization initiatives, such as tariff reductions and the opening of new sectors to foreign investment, further enhanced Pakistan's attractiveness as an investment destination. Industrialization has shown a steady upward trend over the years, with a slight downturn in 2019 due to the economic disruptions caused by the COVID-19 pandemic, followed by a recovery in 2021.

3.1. Autoregressive Distributed Lag (ARDL) Model

Four of the variables—CO2, GDPPC, IND, and FDI show stationarity at first difference. The fifth variable PG shows stationarity at the level, as shown by the Augmented Dicky Fuller method. The Autoregressive Distributed Lag (ARDL) model works well in this case because some factors stay the same at the level and others stay the same at the first difference. A significant number of researchers have employed ARDL model, which mixes autoregressive and moving average parts by adding past values of factors. It does a decent job of dealing with non-stationarity and stopping false decline. The ARDL model is particularly useful for cointegration analysis, which looks at how factors are linked over time. It can handle variables that are integrated at order one and variables that are integrated at order zero. Because the model is flexible, it is possible to pick lag times that work well and use tests like the limits test to see if there is a long-run stability.

The ARDL equation for the regression analysis is given below.

$$\Delta \ln CO2_t = \beta_0 + \beta_1 \Delta \ln GDPPC_{t-1} + \beta_2 \Delta lnIND_{t-1} + \beta_3 \Delta lnFDI_{t-1} + \beta_4 PG_t + \alpha_1 \Delta lnCO2_{t-1} \alpha_2 \Delta lnGDPPC_{t-1} + \alpha_3 \Delta lnIND_{t-1} + \alpha_4 \Delta lnFDI_{t-1} + \varepsilon_t \quad (1)$$

A more precise form of the equation is:

$$\Delta \ln CO2_t = \beta_0 + \Sigma_{i=1}^{4} \beta_1 \Delta ln X_{it} + \Sigma_{j=1}^{4} \alpha_j \Delta \ln X_{it-j} + \beta_5 PG_t + \varepsilon_t \quad (2)$$

Where:

- X_{it} represents the independent variables: $GDPPC$, IND, and FDI.
- β_0, β_1 … β_5 are the coefficients.
- ε_t is the error term.

This model successfully represents time-related fluctuations in the short term as well as the enduring connection between the variables in the long term. For estimating in the short term, we can use the factors β_0, β_1…β_5. Finally, it is important to use stationarity tests, changes, and the right modelling methods, like ARDL, to make sure that time series analysis is dependable. Making sure that factors are stationary and that the model is correctly defined helps in accurately describing the underlying patterns of the data and drawing useful conclusions.

4. Results and Discussion

4.1. Descriptive Statistics of Variables

Descriptive statistics provide a concise summary of the central tendency (mean, median, mode), level of variation (range, variance, standard deviation), and distribution shape. These statistics provide information on the average, standard deviation, and distribution of variables, which aids researchers in understanding the fundamental characteristics of the variables being analyzed.

Table 3
Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
CO2	49	0.646	0.190	0.323	0.998
GDPPC	49	707.6	467.526	134.532	1620.743
IND	49	23.485	1.045	21.349	25.060
FDI	49	0.716	0.6362	0.044	3.035
PG	49	2.652	0.797	1.204	4.423

The mean value for CO2 emissions is 0.646 metric tons per capita with a standard deviation of 0.190, ranging from 0.323 to 0.998 metric tons per capita. The mean value of 0.646 shows moderate emissions per person while the value of standard deviation shows that some places have much higher or lower emissions than the average. Higher emissions could mean stricter environmental rules and higher costs, while lower emissions might mean fewer regulations and lower costs. The mean value of GDP per capita is $872.89 with a standard deviation of $467.526, ranging from $278 to $1537. The mean value reflects moderate income per person while the value of standard deviations shows that Income levels vary widely. Higher income means better living standards and economic prosperity, while lower income indicates more economic struggles.

The mean value for annual industrial value addition in current US dollars is 23.485 which Indicates a healthy growth in the industrial sector. with a standard deviation of 1.045, ranging from 21.349 to 25.060 meaning that industrial value addition can vary quite a bit. Higher growth suggests a booming industry, while lower growth might point to slower expansion or economic issues. The mean value of net FDI inflows as a percentage of GDP is 1.5% showing a moderate level of foreign investment with a standard deviation of 0.8%, ranging from 0.3% to 3.1% suggesting foreign investment can range widely. More investment boosts economic growth, while less investment might signal difficulties in attracting foreign money.

The mean annual population growth rate is 2.3% which Indicates moderate population increase with a standard deviation of 0.4%, ranging from 1.5% to 3.5% indicating that growth rates can vary. Faster growth means a larger workforce but could strain resources, while slower growth might lead to an aging population and slower economic growth. While these statistics provide a basic understanding, visualizations such as histograms can offer a more detailed depiction of the data distribution and trends over time.

4.2. Augmented Dicky Fuller Test Results

Table 4 presents the ADF test results for the variables. The population growth rate (PG) is stationary at level, as evidenced by its statistically significant p-value at the 1% level. However, the variables CO2, GDPPC, IND and FDI are not significant at level due to their p-values exceeding 0.05. To achieve stationarity, these variables were first differenced.

Table 4
Unit Root Test

Variables	At level P-value	At first difference P-value	Integration order
CO2	0.312	0.000***	I (1)
GDPPC	0.681	0.000***	I (1)
IND	0.568	0.000***	I (1)
FDI	0.273	0.000***	I (1)
PG	0.006***		I (0)

4.3. ARDL Bound Test

At different significance levels, the presence of a long-term relationship is assessed using critical values. With varying degrees of significance, the F-statistic in this analysis—11.123—exceeds the upper limit I (1) regressors' critical values. As a result, we reject the null hypothesis and confirm that the variables exhibit co-integration.

Table 5
Bound Test

F-Statistics	11.123
I (0)	**I (1)**
2.45	3.52
2.86	4.01
3.25	4.49
3.74	5.06

This result implies that over a prolonged duration, the variables display a robust and interrelated connection. The co-integration phenomenon implies that while short-term estimates might be biased if co-integration is present, the long-term estimates derived from the model are reliable. Understanding this relationship provides deeper insights into the dynamics of the variables over time, allowing for the exploration of novel approaches to analyze these connections.

4.4. Long-run Estimates of ARDL

The long-run values in the ARDL model represent the stable form of the independent variable coefficients. This is achieved by stationarity-reaching differencing of the variables. Examining these principles helps us to understand the long-term patterns and the factor equilibrium.

Table 6
Long run Results of ARDL

Variable	Coefficient	Std. Error	t-Statistics	P-value
GDPPC	0.331	0.175	1.902	0.051*
IND	-0.371	0.182	-1.881	0.031*
FDI	0.061	0.019	3.171	0.000***
PG	0.010	0.007	1.401	0.142

The long estimation results show that if GDP per capita goes up by 1%, CO2 emissions per person will go up by 0.3% (Abbasi et al., 2021; Bakhsh et al., 2017; Khan et al., 2020; Nawaz et al., 2019). For example, if the GDP per capita went from $10,000 to $11,000, that would mean that 3% more CO2 would be released into the air, or from 1 to 1.03 tonnes. Findings like these show that the rate of increase in CO2 emissions goes up as an economy grows, but it goes down as GDP grows. Supporting the Environmental Kuznets Curve (EKC) idea, when the industry value-added growth rate goes up by 1%, CO2 emissions per person go down by 0.3%. This point of view says that emissions go up at the start of development but go down as countries grow and adopt cleaner technologies. 3% less CO2 would be released into the air for every person if the industry value-added growth rate went from 5% to 5.5%. That's equal to 0.97 tonnes of CO2 per person.

For every one percent rise in foreign direct investment, CO2 emissions per capita rise by 0.06 percent. For instance, a 0.6% rise in CO2 emissions per person (from 1 tonne to 1.006 tons) is the outcome of a 10% increase in FDI inflows (from $100 million to $110 million). This suggests that while FDI slightly increases CO_2 emissions due to heightened economic activity, other factors may have a more significant impact. Population growth is not statistically significant in the long run, indicating its impact on CO_2 emissions per capita is minimal based on the regression results (Bakhsh et al., 2017; Ghazouani, 2022).

4.5. Short-run Estimates of ARDL

The ARDL Error Correction Model analyzes both short- and long-term dynamics in time series data. Long-run estimates reveal sustained variable relationships, while short-run estimates show immediate responses to shocks and adjustments. This model highlights the nuanced interplay amidst economic growth, industrial activity, FDI, and CO_2 emissions, emphasizing the need to consider both perspectives in policymaking.

Table 7
Short run Results of ARDL

Variable	Coefficient	Std. Err.	t-statistics	P-value
GDPPC	-2.212	0.134	-1.59	0.121
IND	0.292	0.144	2.02	0.050*
FDI	-0.020	0.014	-1.43	0.161
ECT	-1.149	0.165	-6.96	0.000***

The short run results show that there is no immediate relationship of GDP per capita with CO_2 emissions per capita, likely due to resistance to energy system changes and delays between economic growth and environmental impacts. A 1% increase in industry value-added growth brings about 0.2% rise in CO_2 emissions per capita, supporting the EKC hypothesis of a positive but weak short-term relationship. The variable foreign direct investment is not statistically significant in the short run, suggesting FDI's impact on CO_2 emissions is delayed or gradual, potentially leading to future changes in industry structure and technological advancement.

The error correction term (ECT) shows a strong tendency for the system to return to long-term equilibrium quickly after a disturbance. A substantial negative coefficient (e.g., -

1.14) indicates a robust and rapid adjustment process, highlighting the system's resilience in correcting deviations.

4.6. Robustness Tests

Diagnostic tests in regression analysis are performed to evaluate the soundness of the underlying assumptions of the regression model and to detect possible issues like heteroscedasticity, autocorrelation, and outliers. Portmanteau white noise test for time series data is used for testing for white noise or randomness in the residuals. The p-value for the Portmanteau (Q) statistic is 0.986, and it is 3.797. This suggests that, at a significance level of 5%, we do not have enough data to rule out the null hypothesis that the residuals are just noise. In other words, there is not enough data to infer that the residuals include serial correlation.

For a particular lag order, the Breusch-Godfrey LM test finds autocorrelation in the residuals of the regression model. Up to the designated latency, the null hypothesis assumes no serial correlation. At the 5% significance level, the p-value of 0.188 indicates that the null hypothesis is not rejected. Therefore, based on this information, we are unable to establish that there is serial correlation in the residuals.

White's test is employed to assess the constancy of variance (homoskedasticity) in the residuals of a regression model. The test checks whether the variability of errors is consistent across observations. Variants of White's test include the White's Information Matrix (IM) test and the traditional White's test. The null hypothesis assumes homoskedasticity, implying constant residual variance. The alternative hypothesis suggests unrestricted heteroskedasticity, indicating varying residual variance. Given a p-value of 0.35, which is more than the p value at significance level of 0.05, we do not reject the null hypothesis. Therefore, the data does not provide evidence of heteroskedasticity.

Table 8
Diagnostic Tests

Portmanteau White Noise Test	
Q Statistics	3.797
Prob >Chi2	0.986
Breush-Godfrey LM Test	
Chi-2	1.72
P-value	0.188
Homoskedasticity and (IM) Test	
Chi-2	46.8
P-value	0.35

When analyzing time series data, the Durbin-Watson (DW) test may identify first-order autocorrelation. A result of the test statistic close to 2 indicates no autocorrelation; the range is 0 to 4. Significant deviations from 2 (usually less than 1.5 or more than 2.5) indicate the existence of autocorrelation. In our case, the test statistic is 2.044, suggesting no first-order autocorrelation in the residuals.

5. Conclusion and Policy Recommendations

This study examines the multifaceted linkage between industrialization, economic growth, and carbon dioxide emissions in Pakistan. The results reveal a notable increase in carbon dioxide emissions per person throughout periods of industrial development and economic prosperity. This underscores the environmental obstacles encountered by developing countries such as Pakistan in the midst of swift development. The rising energy needs of Pakistan's developing economy, which mostly relies on non-renewable energy sources like gas and oil, are primarily to blame for the country's rise in CO2 emissions per person. The reliance on fossil fuels has escalated carbon emissions, thereby affecting the long-term sustainability of the environment. The study underscores the part of population growth and foreign direct investment (FDI) inflows in influencing CO2 emissions per capita. While long-term FDI inflows have a minor impact on carbon emissions, their immediate effects are statistically insignificant, suggesting a delayed environmental impact of FDI.

This study has found a link between GDP per capita, CO2 emissions per capita, and industry value added, and supports the idea that these factors will be linked and influence each other in the short run as well in the long run. This means that carbon emissions would increase as a result of economic growth. The small drop in the industrial value-added index over time, on the other hand, shows that environmental damage can be separated from economic growth by making the process of industrialization more efficient with usage of better and modern technologies. Pakistan must act swiftly to mitigate the environmental impact of industrialization and economic growth. While industrialization has boosted the economy, it has exacerbated environmental problems, particularly CO2 emissions. To address these issues, we must rapidly transition to cleaner energy sources, improve energy efficiency, and promote eco-friendly business practices. The study's findings indicate that long-term environmental protection requires a strategy that distinguishes economic growth from carbon pollution. Through the promotion of energy efficient technologies, the implementation of strict environmental regulations, and providing incentives for green investments, this can be achieved.

Based on the outcomes of the present research, the policy recommendations follow: First, Pakistan should encourage clean tech investment in cooperation with colleges and by means of tax incentives. This will lower industrial operations and manufacturing carbon emissions. Second, Pakistan should establish stricter environmental criteria for foreign direct investments (FDI) that have to apply sustainable development concepts and clean technologies to lessen the effect of FDI-driven economic expansion on the surroundings. Third, develop a cap-and-trade system or carbon fees to make businesses answerable for environmental damage and inspire them toward more ecologically friendly energy sources.

Fourth, creating an energy fund to enable the financial grants for investments in green energy technologies and energy-efficient tools help lower CO_2 emissions by facilitating the change of sectors moving from other sources of power to clean technology. Fifth, Pakistan should pledge to ecologically friendly public transportation options include subways to reduce CO_2 emissions in cities that would produce clean air and improved quality of urban life and electric-powered bus rapid transit lines. To reach its sustainable development goals and ensure a future that is both ecologically benign and rich for next generations, Pakistan has to implement a thorough strategy including social, environmental, and economic elements.

Authors' Contribution

Syed Laulak Haider: data analysis and data interpretation
Wasif Mehdi: data interpretation and writing original draft
Syed Muhammad Mustafa: data collection and writing original draft
Syed Waqar Abbas: study design and critical revision

Conflict of Interests/Disclosures

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