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Climate Change Adaptation and Economic Growth: Empirical Evidence from Pakistan

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Abstract
This study is a contribution to empirics of climate change and economic growth in Pakistan. This study considered annual data from 1990 to 2024. This study intends to use the gross domestic product (GDP) per capita in current US Dollars. The proxy used for investment is gross fixed capital formation (GFCF). The data of GFCF is in a total amount in US Dollars. The TRADE data is in total trade in one year as a percentage of GDP. The data of CO_2 is in total carbon dioxide emissions (kt). We performed auto regressive distributed lag (ARDL) bound testing design to measure long run as well as the short-run association of climate change with economic growth. The notable finding suggests that CO_2 significantly affect the economic growth. In addition, economic growth is also significantly affected by temperature. Such results highlight that CO_2 and TEMP adversely affect the economic growth of Pakistan. There is the positive but minimal impact of RAIN on economic growth of Pakistan. The notable finding suggests that CO_2 which was significant negative in long run has an insignificant effect in short run of Pakistan. However, the coefficient of $CO_2$is still negative in short run.
Keywords: Climate Change, Pakistan, Economic growth, ARDL

1. Introduction
The relationship between sustained economic growth and environmental sustainability remains one of the most extensively debated issues in environmental economics. Traditionally, economic growth has been viewed as incompatible with environmental preservation, as the growth process depends heavily on natural resources both as inputs for production and as sources of energy. This reliance inevitably leads to environmental degradation through the generation of waste in the form of solid, liquid, and gaseous emissions. A pessimistic strand of literature argues that limiting economic growth is necessary to protect environmental quality (Mishra et al., 2023) . Conversely, a more optimistic perspective suggests that economic growth and environmental sustainability can coexist, particularly through the adoption of green technologies and sustainable production and consumption practices that reduce environmental harm (Kamran et al., 2022) .

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DIALOGUE SOCIAL SCIENCE REVIEW
Vol. 4 No. 3 (March) (2026)

In this context, the concept of Sustainable Consumption and Production (SCP) has gained significant policy relevance, especially in developing countries such as Pakistan. The initiative "Strengthening Pakistan's National Policy Frameworks to Facilitate Resource Efficiency and Sustainable Consumption and Production" reflects the country's commitment to aligning its economic policies with the Sustainable Development Goals (SDGs), particularly those related to climate action (Sharifi et al., 2024). This program, implemented by Pakistan's Ministry of Climate Change in collaboration with the United Nations Environment Programme (UNEP), emphasizes resource efficiency and environmental sustainability as key drivers of long-term economic development (Panda et al., 2024).

The nexus between climate change mitigation, adaptation costs, and economic growth is complex and involves significant trade-offs (Abedi & Moeenian, 2021) . Economic growth is typically achieved through increased investment and productive capacity; however, reallocating resources toward climate mitigation efforts, especially those that do not yield immediate economic returns may slow down economic growth. This issue is particularly critical for developing economies, where financial constraints limit the capacity to invest simultaneously in growth and environmental protection. Furthermore, climate-sensitive sectors such as agriculture are highly vulnerable to climate variability and exhibit limited adaptive capacity, thereby increasing the susceptibility of developing countries to climate-induced economic shocks (Abid et al., 2023) .

A substantial body of empirical literature highlights the strong interrelationship between energy consumption, carbon dioxide (CO_2) emissions, and economic growth. Rapid industrialization and increased energy demand, particularly in emerging economies, have significantly contributed to rising global emissions. Studies indicate that higher levels of economic activity are generally associated with increased energy consumption and, consequently, higher CO_2 emissions (Li et al., 2023) For instance, China and Pakistan alone account for a substantial share of global incremental energy demand, thereby intensifying environmental pressures. It has been estimated that global CO_2 emissions continue to rise due to economic expansion, further exacerbating climate change challenges (Azhar et al., 2019) . Empirical evidence from Asian countries such as India, Bangladesh, and Sri Lanka also confirms a strong linkage between economic growth, energy consumption, and CO_2 emissions (Albassam et al., 2025).

From a policy standpoint, economic growth remains a central objective for governments worldwide. However, the environmental consequences of growth-oriented policies cannot be overlooked. A key concern is whether stringent climate policies aimed at reducing emissions could lead to unintended economic consequences, such as increased unemployment, rising poverty levels, and fiscal imbalances. These concerns underscore the importance of designing balanced policy frameworks that integrate economic growth with environmental sustainability (He et al., 2024).

Despite the expanding global literature, empirical research examining the impact of climate change on economic growth in Pakistan remains limited (Khan & Khan, 2025;) . This study aims to address this gap by analyzing the role of key climatic factors, namely temperature, rainfall, and CO_2 emissions, in shaping Pakistan's economic performance. Specifically, the

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Vol. 4 No. 3 (March) (2026)

study seeks to determine whether temperature significantly influences economic growth and to identify the most critical climatic determinants affecting economic outcomes. Preliminary findings indicate that CO_2 emissions and temperature exert a significant negative impact on economic growth, whereas rainfall demonstrates a positive but statistically insignificant relationship. Notably, CO_2 emissions have a stronger negative effect in the long run, while temperature consistently affects economic growth negatively in both the short and long run. These findings highlight the adverse implications of climate change for Pakistan's economic trajectory and emphasize the need for effective environmental policies (He et al., 2024). Pakistan's contribution to global CO_2 emissions, although relatively modest, has increased substantially over time. According to the International Energy Agency (IEA), CO_2 emissions in Pakistan rose from approximately 150.66 million tons in 1990 to over 320.7 million tons, indicating a significant upward trend (Ali Shams et al., 2026). This increase underscores the growing environmental challenges faced by the country and reinforces the importance of examining the relationship between climate variables and economic growth.

Therefore, this study provides a comprehensive analysis of the impact of climatic factors on economic growth in Pakistan by incorporating key macroeconomic variables, including Gross Domestic Product (GDP), Gross Fixed Capital Formation (GFCF), labor force (LF), trade openness (TRADE), temperature (TEMP), rainfall (RAIN), and CO_2 emissions. The remainder of the paper is structured as follows: Section 2 reviews the relevant literature; Section 3 outlines the methodology and model specification; Section 4 presents the empirical results; and Section 5 concludes with policy implications and recommendations.

2. Literature Review

A substantial body of literature has examined the various channels through which climate change influences economic growth, providing both theoretical and empirical evidence of its adverse effects. Climate change impacts economic performance through multiple pathways. First, extreme weather events such as floods, droughts, soil erosion, and biodiversity loss can severely disrupt ecosystems, thereby undermining productive capacity and long-term economic growth. Second, the allocation of financial resources toward climate mitigation and adaptation may reduce investments in critical sectors such as physical infrastructure, research and development, and human capital formation, ultimately constraining economic expansion (Aman & Muhammad Uzair Aman, 2025).

Early empirical contributions in this field highlight the significance of climatic variables in explaining cross-country income disparities. For instance, Sachs (2001) argues that geographic and climatic factors play a crucial role in determining economic development, particularly in regions such as South Asian countries (Pradhan et al., 2024). The study finds a strong negative association between temperature and economic productivity, suggesting that warmer climates tend to exhibit lower levels of income and output. This perspective underscores the importance of environmental conditions as fundamental determinants of economic performance.Subsequent research has further strengthened the empirical linkage between climate change and economic growth. (Pradhan et al. (2024) conducted a comprehensive global analysis using panel data spanning over five decades and found that increases in temperature significantly reduce economic growth in developing countries, while the effect remains statistically insignificant in developed economies. Their findings reveal that rising temperatures adversely affect industrial output, agricultural productivity, investment levels, and political stability in low-income countries. In contrast, precipitation was found to have an insignificant impact on economic growth, indicating that temperature is a more critical climatic variable in shaping economic outcomes (Deka et al., 2025) . Similarly, Adhikari et al. (2024) examined the long-term relationship between temperature and economic growth across multiple countries and reported that a 1°C increase in temperature could reduce economic growth by approximately 0.27 percentage points, particularly in African economies. Their findings emphasize that climate change disproportionately affects developing regions due to their higher dependence on climate-sensitive sectors and limited adaptive capacity. This evidence further confirms the existence of a strong negative relationship between climate change and economic growth (Aman & Muhammad Uzair Aman, 2025) . The mechanisms through which temperature influences economic growth have also been explored in the literature. (Albassam et al., 2025) suggest that rising temperatures affect economic performance through three primary channels. First, higher temperatures directly reduce labor productivity, particularly in outdoor and agriculture-based activities. Second, they negatively influence both the level and growth rate of output by disrupting production processes. Third, increased temperatures contribute to political instability and social unrest, which further hinder economic development. Empirical estimates indicate that a 1% increase in temperature in developing countries may lead to a reduction in economic growth by approximately 1.3% (Kotz et al., 2024) . From a theoretical perspective, the role of endogenous technological change and capital formation has also been highlighted as a key determinant of the climate growth relationship. Pradhan et al. (2024) argue that when technological progress is endogenous, the impact of climate change on economic growth becomes more pronounced through its effects on capital accumulation and innovation. In this context, dynamic effects such as reduced incentives for investment and technological development are more significant than direct damages. Long-run projections suggest that climate change could reduce global GDP by up to 15% under a 3°C increase in temperature, particularly when savings behavior and capital formation are taken into account (Shams` et al., 2025) . Another important strand of literature focuses on the role of income levels and adaptive capacity in mitigating the impacts of climate change. Higher-income countries are generally better equipped to cope with environmental shocks due to their advanced infrastructure, technological capabilities, and institutional frameworks. (Aman & Muhammad Uzair Aman, 2025) find a negative relationship between income levels and disaster-related mortality, indicating that wealthier countries experience lower human and economic losses from climate-related events. This suggests that economic development itself can act as a buffer against the adverse effects of climate change (Azhar et al., 2019).

Several adaptation strategies have been identified in the literature to reduce vulnerability to climate change. These include investments in resilient infrastructure, technological innovation, disaster preparedness, and the development of financial instruments such as insurance mechanisms. Developed

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DIALOGUE SOCIAL SCIENCE REVIEW
Vol. 4 No. 3 (March) (2026)

countries have made significant progress in implementing such measures, enabling them to maintain higher levels of productivity and living standards despite environmental challenges (Neira et al., 2023; Shams` et al., 2025) . In contrast, developing countries often lack adequate infrastructure, institutional capacity, and financial resources to effectively respond to climate risks (Panda et al., 2024). The disparity between developed and developing countries in terms of climate resilience is particularly evident in areas such as water management, sanitation, and agricultural protection. Developed nations typically have robust systems for water filtration, sanitation, and disaster response, whereas developing countries face challenges such as unreliable water supply, inadequate sanitation, and the absence of crop insurance schemes. As a result, climate-related events such as heavy rainfall or droughts tend to have more severe economic and social consequences in developing regions. For example, between 2020 and 2024, approximately one in 19 individuals in developing countries was affected by climate-related disasters annually, compared to only one in 1,500 individuals in OECD countries (Uddin et al., 2024).

In the 21st century, climate change has emerged as one of the most critical global challenges, with particularly severe implications for regions such as Africa and South Asia. These regions are characterized by high dependence on climate-sensitive sectors, geographical vulnerability, and limited adaptive capacity. The impact of climate change on key sectors including agriculture, forestry, tourism, and overall economic productivity, is substantial and continues to pose significant risks to sustainable development (Jain et al., 2022). Overall, the existing literature provides strong evidence that climate change negatively affects economic growth, particularly in developing countries. However, the extent of this impact varies depending on factors such as income level, institutional quality, and adaptive capacity. Despite the growing body of international research, country-specific studies, particularly for Pakistan, remain limited (Zaidi et al., 2018), thereby justifying the need for further empirical investigation.

2. Literature Review

A substantial body of literature has examined the various channels through which climate change influences economic growth, providing both theoretical and empirical evidence of its adverse effects. Climate change impacts economic performance through multiple pathways. First, extreme weather events such as floods, droughts, soil erosion, and biodiversity loss can severely disrupt ecosystems, thereby undermining productive capacity and long-term economic growth. Second, the allocation of financial resources toward climate mitigation and adaptation may reduce investments in critical sectors such as physical infrastructure, research and development, and human capital formation, ultimately constraining economic expansion (He et al., 2024) . Early empirical contributions in this field highlight the significance of climatic variables in explaining cross-country income disparities. For instance, Sachs (2001) argues that geographic and climatic factors play a crucial role in determining economic development, particularly in regions such as Sub-Saharan Africa. The study finds a strong negative association between temperature and economic productivity, suggesting that warmer climates tend to exhibit lower levels of income and output. This perspective underscores the importance of environmental conditions as fundamental determinants of economic performance (DasGupta & Roy, 2025). Subsequent research has further strengthened the empirical linkage

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Vol. 4 No. 3 (March) (2026)

between climate change and economic growth. Kotz et al. (2024) conducted a comprehensive global analysis using panel data spanning over five decades and found that increases in temperature significantly reduce economic growth in developing countries, while the effect remains statistically insignificant in developed economies. Their findings reveal that rising temperatures adversely affect industrial output, agricultural productivity, investment levels, and political stability in low-income countries. In contrast, precipitation was found to have an insignificant impact on economic growth, indicating that temperature is a more critical climatic variable in shaping economic outcomes (Deka et al., 2025) .

Similarly, Adhikari et al. (2024) examined the long-term relationship between temperature and economic growth across multiple countries and reported that a 1°C increase in temperature could reduce economic growth by approximately 0.27 percentage points, particularly in African economies. Their findings emphasize that climate change disproportionately affects developing regions due to their higher dependence on climate-sensitive sectors and limited adaptive capacity. This evidence further confirms the existence of a strong negative relationship between climate change and economic growth (Albassam et al., 2025) . The mechanisms through which temperature influences economic growth have also been explored in the literature. (Bokhari & Syed, 2025) suggest that rising temperatures affect economic performance through three primary channels. First, higher temperatures directly reduce labor productivity, particularly in outdoor and agriculture-based activities. Second, they negatively influence both the level and growth rate of output by disrupting production processes. Third, increased temperatures contribute to political instability and social unrest, which further hinder economic development. Empirical estimates indicate that a 1% increase in temperature in developing countries may lead to a reduction in economic growth by approximately 1.3%. From a theoretical perspective, the role of endogenous technological change and capital formation has also been highlighted as a key determinant of the climate–growth relationship. (Li et al., 2023) argue that when technological progress is endogenous, the impact of climate change on economic growth becomes more pronounced through its effects on capital accumulation and innovation. In this context, dynamic effects such as reduced incentives for investment and technological development are more significant than direct damages. Long-run projections suggest that climate change could reduce global GDP by up to 15% under a 3°C increase in temperature, particularly when savings behavior and capital formation are taken into account (Abid et al., 2023). Another important strand of literature focuses on the role of income levels and adaptive capacity in mitigating the impacts of climate change. Higher-income countries are generally better equipped to cope with environmental shocks due to their advanced infrastructure, technological capabilities, and institutional frameworks. (Ullah et al., 2025) find a negative relationship between income levels and disaster-related mortality, indicating that wealthier countries experience lower human and economic losses from climate-related events. This suggests that economic development itself can act as a buffer against the adverse effects of climate change (Ayaad & Oukaili, 2023) . Several adaptation strategies have been identified in the literature to reduce vulnerability to climate change. These include investments in resilient infrastructure, technological innovation, disaster preparedness, and the development of financial instruments such as insurance mechanisms. Developed countries have made significant progress in

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Vol. 4 No. 3 (March) (2026)

implementing such measures, enabling them to maintain higher levels of productivity and living standards despite environmental challenges (Kazemi et al., 2024) . In contrast, developing countries often lack adequate infrastructure, institutional capacity, and financial resources to effectively respond to climate risks. In the 21st century, climate change has emerged as one of the most critical global challenges, with particularly severe implications for regions such as Africa and South Asia. These regions are characterized by high dependence on climate-sensitive sectors, geographical vulnerability, and limited adaptive capacity. The impact of climate change on key sectors, including agriculture, forestry, tourism, and overall economic productivity substantial and continues to pose significant risks to sustainable development (Rifai et al., 2023) Overall, the existing literature provides strong evidence that climate change negatively affects economic growth, particularly in developing countries. However, the extent of this impact varies depending on factors such as income level, institutional quality, and adaptive capacity. Despite the growing body of international research, country-specific studies, particularly for Pakistan, remain limited, thereby justifying the need for further empirical investigation.

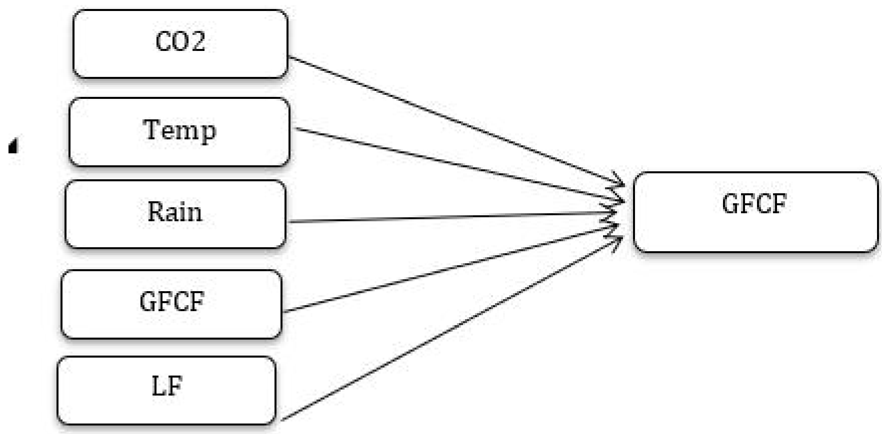

Figure 1: Conceptual Framework

3. Methodology

The study uses ARDL bounds testing approach. Variables include GDP growth (dependent), CO2, temperature, labor force, rainfall, and capital formation (independent constructs).

3.1 Data

The primary objective of this study is to conduct an empirical analysis of the impact of climate change on Pakistan's economic growth. A new study analyzed annual data spanning from 1990 to 2024.The primary concern was data availability; hence, we determined the time period based on this criterion. The data for various variables in this study is obtained from the World Development Indicators, the Pakistan Statistical Yearbook, and the State Bank of Pakistan. The present study aims to utilize the gross domestic product (GDP) per capita in current US Dollars. The proxy employed for investment is gross fixed capital formation (GFCF). The GFCF data is presented as a total amount in US Dollars. The labor force (LF) data represents the overall labor force during a given year. The TRADE statistic represents total trade within a year as a percentage of GDP. The CO2 data represents total carbon dioxide emissions (kt). The temperature

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Vol. 4 No. 3 (March) (2026)

data (TEMP) is expressed as the mean in degrees Celsius over one year. The RAIN data represents total rainfall measured in millimeters. The aims of this research are 1) to examine the correlation among GDP, gross fixed capital formation, labor force, trade, temperature, rainfall, and carbon dioxide emissions in Pakistan, and 2) to analyze the impact of climate change on economic growth.

3.2 Econometric Model

The variables' econometric specification can be expressed as follows: $DPt = \alpha + \beta_1 GFCF_t + \beta_2 LF_t + \beta_3 TRADE_t + \beta_4 CO2_t + \beta_5 TEMP_t + \beta_6 RAIN_t + \varepsilon_t$ (1)
In equation (1), GDP represents the gross domestic product per capita in current US Dollars; GFCF is gross fixed capital.

The impact of climate change on economic growth: evidence from Pakistan. LF is the labor force; TRADE is the yearly trade as a percentage of GDP; CO_2 is the total carbon dioxide emissions (kt); TEMP is the total temperature in centigrade in one year; and RAIN is the total rainfall in millimeters.

3.3 The Autoregressive Bounds Testing (ARDL) Model

We are employing the auto-regressive distributed lag (ARDL) bound testing approach recommended by (Farhani & Ozturk, 2015) in the current investigation. Measure the relationship between economic growth and climate change in both the short and long term. ARDL is suitable for models that are a combination of I (0) and I (1) variables. Another attribute of this model is its suitability for small sample sizes, as our sample size is limited to (Bokhari & Syed, 2025). Equation (1) is transformed into an ARDL equation.
The ARDL short-run and long-run models are symbolically represented by equations (2) and (3).

$$GDP_t = c + \beta_1 GDP_{t-i} + \beta_2 GFCF_{t-i} + \beta_3 LF_{t-i} + \beta_4 TRADE_{t-i} + \beta_5 CO2_{t-i} + \beta_6 TEMP_{t-i} + \beta_6 RAIN_{t-i} + \varepsilon_t$$

$$\Delta GDP_t = c + \alpha_1 \sum_{i=1}^{p} \Delta GDP_{t-1} + \alpha_j \sum_{j=1}^{p} \Delta GFCF_{t-j} + \alpha_k \sum_{k=1}^{p} \Delta LF_{t-k} + \alpha_l \sum_{l=1}^{p} \Delta TRADE_{t-l} + \alpha_m \sum_{m=1}^{p} \Delta CO2_{t-m} + \alpha_n \sum_{n=1}^{p} \Delta TEMP_{t-n} + \alpha_n \sum_{n=1}^{p} \Delta RAIN_{t-n} + ECM_{t-1}$$

The parameters specified in Equation (2), namely β_1, β_2, β_3, β_4, β_5, and β_6, represent the long-run coefficients, whereas the parameters in Equation (3), α_1, α_2, α_3, α_4, α_5, and α_6, denote the short-run coefficients. The operator Δ indicates the first difference of the variables, and ECM_{t-1} captures the speed of adjustment toward long-run equilibrium. Prior to estimating the ARDL model, it is necessary to examine the existence of a long-run relationship among the variables using the Bounds Testing approach. This procedure involves estimating a conditional error correction model and applying an F-test to assess the joint significance of the lagged level variables. The computed F-statistic is then compared with the critical values reported by (Anderson & Gerbing, 1992; Hox,

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Vol. 4 No. 3 (March) (2026)

2021); if the estimated value exceeds the upper bound critical value, it confirms the presence of a long-run equilibrium relationship among the variables, otherwise, no such relationship exists.

4. Empirical Results

4.1 Unit Root Test

It is imperative to determine the stationarity of the variables prior to conducting bounds testing. The Augment Dickey and Fuller (1979) test is employed to evaluate the stationarity of the variables. Table 1 contains the findings of the unit root test (Enders & Lee, 2012) . The findings indicate that the majority of variables are stationary at the first difference, while only a small number of variables are stationary at the level. The findings indicate that GDP, GFCF, LF, CO2, and RAIN are significant stationary at the first difference. Nevertheless, the TRADE and TEMP remain at their current levels. The validity of the ARDL bounds testing model is substantiated by these results.

Table 1: ***Unit Root Test***

Variables	Level	1st Difference	Inference
GDP	-0.5434	-9.5336	I (1)
GFCF	-0.6657	-8.8674	I (1)
LF	-1.9234	-10.9331	I (1)
TRADE	-3.0606		I (0)
CO2	-1.9747	-8.0992	I (1)
CO2 (2)	-3.1746		I (0)
RAIN	-1.0874	-5.2597	I (1)

4.2 Bound Testing Approach

Before estimating the long-run ARDL model, the bound's testing approach was implemented to investigate the existence of a long-term relationship between the dependent and explanatory variables. The bounds test results, as shown in Table 2, indicate that the calculated F-statistic surpasses the upper bound critical value, thereby verifying the existence of a statistically significant long-term association between the variables.

Table 2: ***Bound Testing Results***

Country	F-value (3)	Lag Length	Significance Level	I (0)	I (1)
Pakistan (GDP)	9.7215	1	1%	2.96	4.26
Pakistan (GDP)	9.7215	1	5%	2.32	3.5
Pakistan (GDP)	9.7215	1	10%	2.2	3.13

4.3 Long Run Equation Results

Table 3 shows the long-run estimation results of the ARDL model. Findings show that gross fixed capital formation (GFCF) has a negligible effect on long-term economic growth. The labor force is a significant factor in Pakistan's economic growth, with a high coefficient value of 0.54, indicating its important role in

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www.thedssr.com

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Vol. 4 No. 3 (March) (2026)

economic expansion. Trade positively and significantly impacts economic growth. Results show that CO2 emissions significantly hinder economic growth, and temperature (TEMP) also has a notable negative impact. These findings highlight the negative impact of environmental factors, including CO2 emissions and rising temperatures, on economic growth in Pakistan. Rainfall has a positive but statistically insignificant effect on economic growth.

Table 3: ***Long Run Equation Results***

Variables	Coefficient	S. E	T-Ratio [Prob]
GFCF	0.10	0.24	0.40 [0.69]
LB	0.55	0.12	4.64 [0.000]
TRADE	0.54	0.23	2.42 [0.02]
CO2	-0.07	0.027	-2.54 [0.01]
TEMP	-0.05	0.02	-2.25[0.035]
RAIN	0.028	0.047	0.596 [0.557]
C	-6.49	2.82	-2.30 [0.031]

4.4 Short Run Equation Results

Table 4 shows the short-run estimation results of the ARDL model. The findings show that gross fixed capital formation (GFCF) has a significant positive impact on economic growth in the short run, but this effect is insignificant in the long run, suggesting that capital aids short-term economic expansion. The labor force is a key factor in economic growth short-term, but its long-term impact is even greater, indicating a stronger contribution over time while still benefiting growth in the short run. Trade has a notable positive effect on Pakistan's economic growth in the short term. CO2 emissions have a significant negative effect in the long run but are insignificant in the short run. The negative coefficient suggests that the adverse impact emerges over time. Temperature (TEMP) has a notable negative impact on economic growth in the short and long term, underscoring its ongoing harmful influence. Rainfall (RAIN) shows a positive but statistically insignificant short-run effect. The error correction term, ECM (-1), is negative and statistically significant, confirming a stable long-run relationship. This indicates that deviations from equilibrium are corrected over time, with an estimated adjustment speed of about 31% per period.

Table 4: ***ARDL Short Run Results***

Variables	Coefficient	Standard Error	T-Ratio [Prob]
dGFCF	0.10	0.049	2.14 [0.04]
dLB	0.17	0.07211	2.36 [0.03]
dTRADE	0.17	0.038	4.51 [0.000]
dCO2	-0.03	0.03	-0.89 [0.38]
dTEMP	-0.26	0.12	-2.2[0.034]
dRAIN	0.009	0.014	0.64 [0.53]
dC	-2.022	1.4969	-1.35 [0.19]
ECT(-1)	-0.312	0.14375	-2.17[0.04]

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www.thedssr.com

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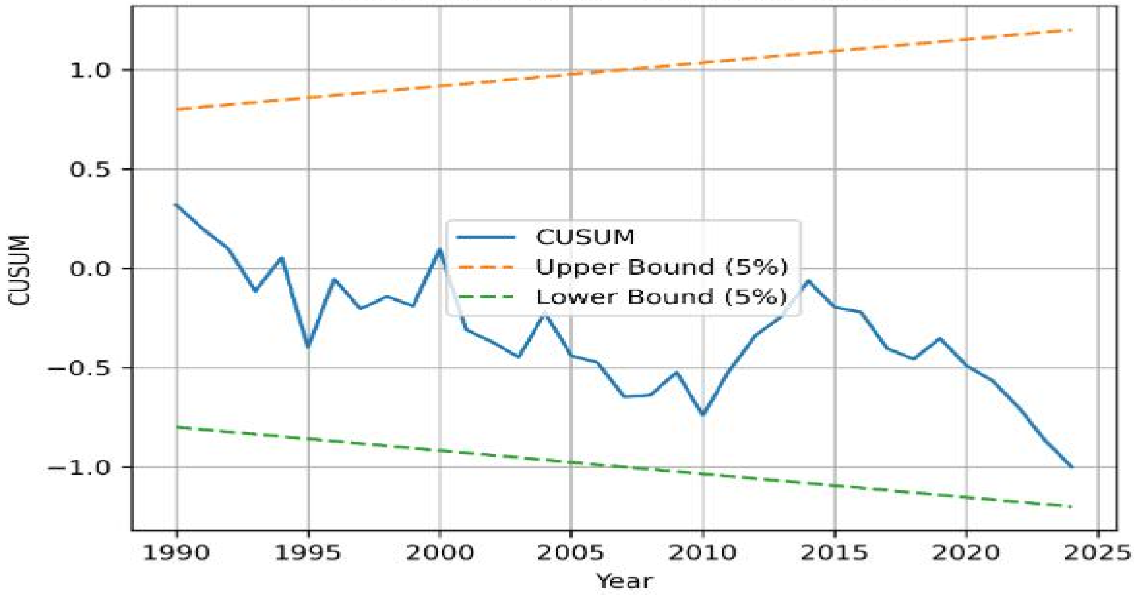
Vol. 4 No. 3 (March) (2026)

Model Statistics	Value
R-Squared	0.74
R-Bar-Squared	0.65
S.E. of Regression	0.01
F-statistic	9.28 [0.000]
Akaike Info Criterion	96.36
Schwarz Bayesian Criterion	89.76
DW-statistic	1.942

4.5 Reliability Test

Lastly, we utilized the cumulative sum (CUSUM) test to assess the model's reliability. Figure 1 clearly shows that the critical values are below the 5 percent significance level. CUSUM square is also within the 5% level of significance, indicating that the model is fit, as shown in Figure 2.

Figure 1: CUSUM Test (1990–2024)



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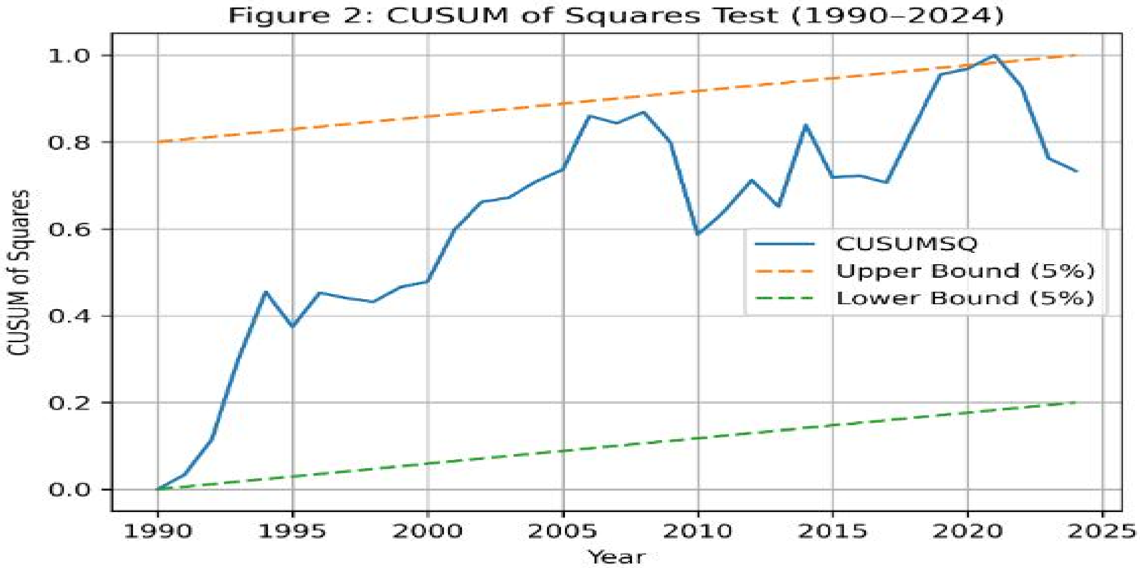
DIALOGUE SOCIAL SCIENCE REVIEW
Vol. 4 No. 3 (March) (2026)



5. Conclusion

This study represents the climate change and economic growth empirics in Pakistan. Though considerable academic research work has been dedicated to climate change, the global effects on long-run growth are not definite. Furthermore, the indication related to Pakistan is mostly anecdotal and primarily limited to what research elsewhere has to say by extrapolation. Therefore, an empirical study is necessary to notify the policymakers and place Pakistan properly in efforts directed to mitigate the consequences of global warming (Uddin et al., 2024) . In this study, the climate change effect on economic growth of Pakistan has been estimated. The novelty of this work explores the various varieties of empirical techniques thereby accounting for the nuances that are left out by extant studies. The short- and long-run consequences of the relationship between growth and climate change are also estimated. It is quite difficult to pin down the relationship precisely; still, this study is able to establish certain trends. We found that trade has a significant positive effect on economic growth of Pakistan. The notable finding suggests that CO_2 has a negatively significant effect on economic growth. In addition, the temperature has also the significant negative effect on economic growth. Such results highlight that CO_2 and temperature adversely affect the economic growth of Pakistan. The RAIN has a positive but insignificant effect on economic growth of Pakistan. The notable finding suggests that CO_2 which was significant negative in long run has an insignificant effect in short run of Pakistan. However, the coefficient of CO_2 is still negative in short run. This result suggests that CO_2 has long run negative effects. The temperature has a significant negative effect on economic growth of Pakistan in short run as well as in long run. The rain has a positive but insignificant effect on economic growth of Pakistan also in short run. Thus, in the long run, countries might have improved to the severe surroundings originating from climate change, accordingly. In the short run, however, climate change effect could be lethal. As Pakistan is an agricultural country, thus, it is summarized that variations in climate change might have negative consequences for agricultural production and industrial growth, poverty reduction and job creation.

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