Policy Journal of Social Science Review

Online ISSN 3006-4635 Print ISSN 3006-4627

Vol. 3 No. 12 (2025)

Energy Transition and Climate Change Dynamics in Pakistan: Implications for Sustainable Economic Growth

[1]Khurram Shahzad
[2]Asma Altaf
[3]Muhamad Yasin Abid
[1]Assistant Professor, Higher Education Department Punjab, Lahore
[2]Lecturer, Hazrat Ayesha Saddiqa Model Degree and Commerce College, Lahore
[3]Assistant Professor, Higher Education Department Punjab, Lahore
[1]sayadbukhari.eco@gmail.com, [2]asmakhaleeq568@gmail.com, [3]myasinabid1983@gmail.com

Abstract

This study examines the dynamic relationship between climate change, energy transition, and economic growth in Pakistan using a time-series framework. Climate change is proxied by carbon dioxide (CO_2) emissions, while energy transition is measured by the share of renewable energy in total final energy consumption. Annual data covering the period 1990–2023 are obtained from the World Development Indicators. To capture both short-run and long-run dynamics, the autoregressive distributed lag (ARDL) bounds testing approach to cointegration is employed. The empirical results indicate the existence of a stable long-run relationship among climate change, energy transition, and economic growth. Findings reveal that energy transition contributes positively to economic growth while significantly reducing CO_2 emissions in the long run, supporting the notion of sustainable growth. In contrast, higher carbon emissions are found to exert an adverse effect on economic growth, highlighting the environmental cost of fossil-fuel-based development. Short-run dynamics show adjustment towards long-run equilibrium, as confirmed by the error correction term. The study offers important policy implications, suggesting that accelerating renewable energy adoption and improving energy efficiency are crucial for achieving climate-resilient and sustainable

Keywords: Climate Change; Energy Transition; Renewable Energy; Economic Growth; CO_2 Emissions; ARDL Model; Time-Series Analysis; Pakistan

Article Details:

Received on 22 Nov, 2025
Accepted on 27 Dec, 2025
Published on 28 Dec 2025

Corresponding Authors*

1. Introduction

Climate change has become one of the most urgent issues of the twentieth century on the planet, which threatens the stability of the economy, the sustainability of the environment, and the well-being of people. The growing global temperatures, frequency of extreme weather patterns, and the rise in the amount of carbon dioxide (CO_2) have raised doubts about the ability of growth models based on fossil fuels to work in the long run. Climate change is especially a threat to developing countries such as Pakistan because they are overly dependent on carbon-intensive sources of energy, population increases is high, adaptive capacity is low, and the demand of energy is increasing. Consequently, the discourse on how to attain economic growth and at the same time reduce climate change has taken a new turn to the energy transition concept that focuses on the gradual substitution of fossil fuels with renewable and cleaner energy sources.

The traditional driver of economic growth has been high energy consumption, which has mainly been through non-renewable sources of energy like coal, oil and natural gas. Even though this growth-energy nexus has enhanced industrialization and helped in creating better living standards, it has also led to high levels of environmental degradation and increasing levels of greenhouse gases. The same trend is evident in the growth trend in Pakistan, in which the energy consumption has been growing steadily to support the energy requirements of industrial growth, urbanization and population growth. Nevertheless, the energy mix of the country is still too controlled by fossil fuels; therefore, the economic development of the country is becoming more carbon-consuming and ecologically unsustainable. This poses a severe policy challenge: what can Pakistan do to maintain its economic development and reduce its carbon footprint and fulfill the international climate commitments?

Pakistan is one of the nations that are most vulnerable to the effects of climate change even though it contributes a rather low percentage of the overall CO_2 emissions to the world. Such climate-related disasters like floods, heat waves, drought and melt-down of glaciers have been more effective and rampant and have come with huge economic burdens and compromised growth prospects. The cataclysmic floods of the recent years have shown how susceptible the Pakistani economy is to climatic shock with impacts on agriculture, infrastructure, energy provision and livelihoods. These issues highlight the importance of a development strategy that is balanced between climate resilience and sustainable economic growth with the focus on energy transition as the theme of the policy discussion. It is widely known that energy transition is one of the most important mechanisms of dealing with climate change and also facilitating long term economic growth. It entails the augmentation of the portion of renewable energy like solar, wind, hydro and biomass in total energy mix, energy efficiency as well as the reliance on fossil fuels. In the case of Pakistan, energy transition can be regarded as both environmental and economic necessity. The fluctuating global oil prices have led to persistent energy unavailability, high energy importation bills and macroeconomic vulnerability to the country. The growth in renewable energy can reduce energy insecurity, reduce the cost of production, and can enhance the stability of the balance-of-payments, hence sustainable growth.

Although energy transition is increasingly being appreciated, the linkage between climate change, energy transition and development in economies is a complex and controversial issue, especially in developing economies. On the one hand, the supporters of renewable energy believe that the adoption of clean energy facilitates green development through the minimization of emissions, growth in energy efficiency, and the establishment of new jobs. Critics have on the other hand argued that switching to non-fossil fuels can have short term economic costs as it requires a lot of initial investment, technology limitations as well as infrastructure limitations. These opposing sides point to the necessity of empirical data to evaluate the possibility of energy transition as both economical and effective in promoting economic growth and mitigating climate change in such nations as Pakistan.

Empirical evidence regarding the connection between energy, environment and growth provides conflicting results. A number of studies indicate that the use of renewable energy has a positive impact on the economic growth and leads to a decrease in the emissions, which justifies the idea of sustainable development. In other cases, it carries a neutral or even negative impact (especially in the short term), because of the adjustment costs, and inefficiencies in the implementation of renewable energy. On the same note, the effects of the CO_2 emissions on economic growth are also contested with some evidence showing the growth promoting effect of the energy-induced emissions and the growth-dampening effect of environmental degradation. Such discrepancies in the literature show that the nexus energy-growth-climate is country-specific and time-dependent, and requires additional analysis of individual economies on a time-series basis. It is on this basis that the current research seeks to examine the dynamic interdependence between climate change, energy transition and economic growth in Pakistan and through a time-series analytical framework. The CO_2 emissions are proxied by climate change, and the composite of renewable energy in the total final energy consumption measures the transition of energy. This is a direct indicator of transition to cleaner energy sources, and hence is a policy-relevant indicator. Economic growth is the real GDP, which shows the performance of the economy. Combining these variables in one empirical model the study gives a holistic evaluation of whether energy transition is able to sustain growth and alleviate climate change in Pakistan.

The research methodology follows the autoregressive distributed lag (ARDL) method, which is highly appropriate in studying time-series data of mixed order of integration and small samples of data. ARDL framework can be used to analyses short-run and long-run relationships between variables, and provides useful data on the dynamics of adjustment and the behavior of an equilibrium. This applies especially to Pakistan where macroeconomic variations and structural reforms in the energy sector are likely to affect the energy-growth-environment nexus in the long run. This study has a three-fold contribution. First, it offers current empirical data on the importance of energy transition in determining the economic growth and environmental performance in Pakistan which is a gap that is critical in the literature. Second, it officially takes into account the climate change as a part of the growth-energy analysis, leaving the traditional energy consumption indicators. Third, the research presents subtle policy details of the form of the differentiation between short-run and long-run impacts, which can be utilized in the design of effective energy and climate policies. The results will guide the policymakers to understand whether speeding up the pace of renewable energy use can sustain Pakistan to have climate-resilient and sustainable economic growth without undermining development goals

The rest of the paper is structured in the following way. Section 2 is a literature review of the theoretical and empirical literature that is relevant. Section 3 contains model specification, sources of data, and the econometric methodology. Section 4 reports on the empirical findings and explains them. Lastly, Section 5 is a conclusion of the study and policy implications

2. Literature Review

The interrelation between energy transition, climate change and economic growth has been increasingly looked into in the recent decades especially in developing economies that are going through structural transition. There is a general consensus among scholars that the conventional growth approaches based on the use of fossil fuels are becoming highly unstructured to the environmental sustainability and that renewable energy use and low-carbon developmental strategies are being rejuvenated. According to early global and regional research, energy transition is a need not just an environmental need but also a possible driver of economic development in the long term under the right institutional and policy framework.

A number of studies which analyzed the global and regional datasets indicate that the impact of renewable and non-renewable energy consumption on economic growth and CO_2 emissions is asymmetric and dynamic. As shown by Asghar et al. (2023), renewable energy consumption positively impacts the emission of carbon gas, but negatively contributes to the worsening of the environment, indicating that renewable energy is a stabilizing factor in the performance of the environment. Likewise, the same studies arrive at similar conclusion as their attention is on emerging and growing economies where the internalization of renewable energy leads to emission decoupling although fossil fuel intensity is a significant contributor to environmental degradation. All of these findings emphasize that the structure of energy consumption instead of energy use is the key to attaining sustainable growth. The renewable energy consumption in the South Asian region based on the regional panel studies offers good evidence that this energy can enhance the quality of the environment and economic growth. Ali et al. (2022) discover that globalization and renewable energy use have a combined positive effect on environmental sustainability, i.e. promoting the reduction of emission intensity, whereas Yasin et al. (2024) reveal that renewable energy and human capital development contribute to a lot in maintaining long-term growth and preventing carbon emissions. Such works substantiate the thesis that energy transition has to be incorporated in more grand development plans that incorporate institutional quality, integration of trade, and human capital formation.

The energy-growth-environment nexus has been studied in Pakistan specific literature which has largely relied on time-series econometric models: ARDL and cointegration analysis. Khan et al. (2020) report having evidence of a long-run correlation between energy consumption, economic growth, and CO_2 emissions and underline the environmental cost of the growth led by fossil fuel. What their results imply is that the reliance of Pakistan on non-renewable sources of energy has played a major role in increasing emissions, and therefore, compromising the prospects of sustainable development. In line with this opinion, Sharif et al. (2019) indicate that both coal, oil, and natural gas use have significant positive impacts on short and long-term carbon emissions, which makes the dependence on fossil fuel a confirmed concern. Further investigations that use dynamic ARDL simulation further confirm that non-renewable energy use and economic development contribute to the degradation of the environment in Pakistan jointly. These findings suggest that long-term pro-growth energy policies entirely relying on fossil fuel are not sustainable developmentally. Nonetheless, there is a more complicated story concerning renewable energy. According to some studies, the long-term impacts of renewable energy use are large, as CO_2 emissions are substantially lowered, whereas short-term aspects are poorly correlated and have negligible impact because of the infrastructural basis and low penetration of renewable energy (Iqbal & Naseem, 2025). This implies that the energy transition in Pakistan is in its infancy and needs continued investment in order to produce tangible environmental positive impacts.

A study specifically concerned with energy transition in Pakistan illuminates structural hassles in the transition of energy mix of fossil fuels to renewable energy sources. According to Raza and Cucculelli (2024), despite the positive effect of renewable energy on the economic growth, the overall effect on emission reduction is limited because fossil fuels are still the dominant energy source in electricity generation. Decomposition-based investigations also show that growth in the renewable energy productivity lowers emissions, and the intensity of fossil fuels and the trade in fossil fuels increases carbon production, indicating the role of energy substitution and not energy growth in nature.

The other role of literature being discussed is the role played by energy efficiency and energy intensity towards the growth and environmental outcomes. The extensive use of high energy intensity is always linked to inefficient production systems and emissions which have adverse impacts on economic outcomes in the long-run. The research on Pakistan reveals which energy efficiency can significantly decrease carbon emissions, and this may contribute to economic growth, thus, energy efficiency is a major addition to the use of renewable energy.

In addition to emissions, the recent literature expands the area of energy transition by analysing its consequences on the sustainability of natural resources. Kiran and Gardezi (2025) discover that an increased use of renewable energy leads to a decreased relying on rents of natural resources, which means that the change of energy will alleviate the pressure on natural ecosystems. Such view takes the energy transition discussion beyond carbon reduction and makes renewable energy a part of global environmental sustainability.

The socioeconomic and demographic factors are also very important in the energy-growth-environment nexus. According to several studies, population growth, urbanization, and foreign direct investment raise the energy demand and output, especially in the developing economies. Empirical data in Pakistan indicates that a growing population is a good contributor to the economic production but at the same time this population growth has a negative impact on environmental pressure unless it is accompanied by cleaner energy sources and good urban planning. It has been established that financial development helps in reducing emissions by enabling investments to cleaner technologies, but unregulated urbanization contributes to the further degradation of the environment. Other comparative studies involving Pakistan in larger samples of South Asia or emerging markets can offer additional information. The analogy of the panels prove that the consumption of renewable energy contributes to the growth of the economy throughout the region on a regular basis and influences the emission in any country according to the institutional and structural peculiarities of the country. Bashir and Saqib (2025) demonstrate that the use of renewable energy with economic growth leads to an increase in emissions, but in the long-run, the curve will lead to a decrease in emissions, which is a known hypothesis of the Environmental Kuznets Curve in South Asia.

It is also maintained in the literature that nonlinear and asymmetric relationships can be significant, as linear models can mask significant transitional dynamics. Nonlinear ARDL studies have found that an increase in the consumption of renewable energy has a greater growth and environmental impact than an equal fall age, whereas a negative shock caused by a decrease in fossil fuel consumption has a disproportionate impact on the environment. These results merit the application of elastic econometric methods that can attain the asymmetric and dynamic effects.

The recent policy oriented and technological research indicates that the decoupling of economic growth and carbon emission can be achieved with the aid of renewable energy implementation, as promoted by the technological innovation and the storage facilities. Sustainability modeling evidence suggests that renewable investments have increased environmental benefits when coupled with supportive institutions and long-term planning. The recent increase in the number of solar energy power plants in Pakistan demonstrates once again that energy transition can take place and change the energy composition of the countries significantly within a short period of time.

Despite the extensive literature, important gaps remain. First, many studies focus on energy consumption rather than explicitly modeling energy transition as a structural shift toward renewables. Second, relatively few Pakistan-specific studies jointly analyze energy transition, climate change, and economic growth within a single time-series framework that distinguishes between short-run and long-run dynamics. Third, the interaction between energy transition and structural factors such as trade openness, energy intensity, and population growth remains underexplored. Addressing these gaps, the present study contributes to the literature by empirically examining the dynamic relationship between energy transition, climate change, and economic growth in Pakistan using a robust ARDL framework.

3. Data & Methodology

3.1. Data

The study utilizes six key variables to analyze the dynamic relationship between economic growth, energy transition, and climate change in Pakistan. The dependent variable, economic growth (GDP), is measured using real GDP at constant 2015 USD, reflecting the overall performance of the economy. The main explanatory variable, energy transition (ET), is proxied by the share of renewable energy in total final energy consumption, capturing Pakistan's shift from fossil fuels toward cleaner energy sources. CO_2 emissions (CO_2) are included to represent climate change and environmental degradation, measured in metric tons per capita. To control for structural and socioeconomic factors, the study incorporates population growth (POP), trade openness (TRD), and energy intensity (EI). Population growth is the annual growth rate of the population, trade openness is measured as the ratio of total trade (exports + imports) to GDP, and energy intensity is captured by the amount of energy used per unit of GDP (MJ/$2017 PPP GDP), reflecting the efficiency of energy use in economic production. All data are collected from internationally recognized and reliable sources, including the World Bank's World Development Indicators (WDI) for GDP, renewable energy, CO_2 emissions, population, trade, and energy intensity. Additional cross-validation and energy-specific data are obtained from the International Energy Agency (IEA), BP Statistical Review of World Energy, and Pakistan's Ministry of Energy (Power Division) and NEPRA reports, ensuring comprehensive and accurate coverage of Pakistan's energy and economic trends over the period 1990–2023.

Table 1: ***Description of Variables***

Variable Name	Symbol	Definition
Economic Growth	GDP	Real GDP, constant 2015 USD
Energy Transition	ET	Share of renewable energy (% of total final energy)
Climate Change	CO_2	CO_2 emissions per capita (metric tons)
Population Growth	POP	Annual %
Trade Openness	TO	Exports + Imports / GDP (%)
Energy Intensity	EI	Energy use per unit GDP (MJ/$2017 PPP GDP)

Source: WDI

3.2. Methodology

This study employs a quantitative time-series research design to examine the dynamic relationship between climate change, energy transition, and economic growth in Pakistan. The study aims to identify both short-run and long-run interactions among the variables using annual data over the period 1990–2023. The autoregressive distributed lag (ARDL) bounds testing approach is adopted because it is suitable for small sample sizes, allows for variables integrated of mixed order (I (0) and I (1)), and distinguishes between short-run and long-run effects. This methodology also accommodates structural changes and policy shocks commonly observed in developing countries' energy sectors. The study formulates the empirical model based on the growth-energy-environment nexus.

The general functional form is as follows:

$GDP_t = f\ (ET_t, CO_{2t}, X_t)$

The corresponding **log-linear ARDL model** is specified as:

$$\Delta LnGDP_t = a_0 + \sum_{i=1}^{n} b_i\,(LnGDP)_{t-i} + \sum_{j=2}^{n} c_j\,(ET)_{t-j} + \sum_{k=0}^{n} d_k\,(Z)_{t-k} + \mu_t$$

Where:

GDP_t =Real GDP at time t (proxy for economic growth)

ET_t=Energy transition indicator at time t (share of renewable energy in total final energy consumption)

Z=Vector of control variables, including Carbon Dioxide, population growth, trade openness, and energy intensity

4. Empirical Findings

4.1. Unit Root Test Results

Before estimating the ARDL model, it is essential to examine the stationarity properties of the time series variables. Both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were employed to determine whether the series are stationary at level or require first differencing.

From Table 2, it can be observed that lnET (Energy Transition) and lnTRD (Trade Openness) are stationary at level, as indicated by their ADF and PP test statistics exceeding the critical values at the 5% significance level. This implies that these variables are integrated of order zero, I(0) and lnGDP (Economic Growth), $lnCO_2$ (CO_2 Emissions), lnPOP (Population Growth), and lnEI (Energy Intensity) are non-stationary at level, failing to reject the null hypothesis of a unit root. However, they become stationary after first differencing, confirming that they are integrated of order one, I(1). This mixed order of integration (I(0) and I(1)) justifies the application of the ARDL bounds testing approach, which can handle variables with different integration orders without requiring all variables to be I(1). Stationarity of variables ensures that the regression results are not spurious, and that meaningful long-run and short-run relationships can be estimated. The results also highlight the importance of differentiating between short-run fluctuations and long-run trends. For example, CO_2 emissions and economic growth are I(1), meaning shocks to these variables can have persistent effects unless countered by adjustments in energy transition, trade, or energy intensity.

The mixed stationarity i.e. non-stationarity at levels but stationarity at first difference, demonstrated by the variables justifies the use of the autoregressive distributed Lag (ARDL) bounds testing approach. The ARDL framework is particularly robust for investigating long-run and short-run relationships in models comprising variables with a mix of I(0) and I(1) properties. This methodological choice ensures the integrity and reliability of the econometric analysis and its conclusions.

Table 2: ***Results of Unit Root Test***

Variable	Level ADF	Level PP	Order of Integration (Level)	1st Diff ADF	1st Diff PP	Order of Integration (1st Diff)
lnGDP	-2.31	-2.45	I(1)	-4.89***	-4.95***	I(1)

Table 2: ***Results of Unit Root Test***

Variable	Level ADF	Level PP	Order of Integration (Level)	1st Diff ADF	1st Diff PP	Order of Integration (1st Diff)
lnET	-3.12*	-3.08*	I(0)	-	-	I(0)
lnCO_2	-1.87	-1.92	I(1)	-5.02***	-5.10***	I(1)
lnPOP	-2.54	-2.49	I(1)	-4.75***	-4.80***	I(1)
lnTRD	-3.21*	-3.18*	I(0)	-	-	I(0)
lnEI	-2.15	-2.23	I(1)	-4.63***	-4.67***	I(1)

Source: Authord own Estimaion

4.2. ARDL Bound Test Results

After confirming the stationarity properties of all variables, the ARDL bounds test was applied to examine the existence of a long-run cointegration relationship among GDP, ET, CO_2, POP, TRD, and EI.

From Table 3, the computed F-statistic = 5.72 exceeds the upper critical bound (I(1) = 3.79 at 5% significance). This indicates the null hypothesis of no long-run relationship is rejected, confirming that a stable long-run equilibrium exists among the variables. The presence of cointegration implies that despite short-run fluctuations due to policy changes, market shocks, or energy price volatility, the variables are tied together in the long run. It validates the estimation of both long-run coefficients (capturing equilibrium relationships) and short-run dynamics (capturing adjustments around the equilibrium). The significance of the long-run relationship suggests that energy transition (ET), CO_2 emissions, population growth, trade openness, and energy intensity collectively influence Pakistan's economic growth over time.

In summary, the unit root tests confirm the suitability of the ARDL approach, while the bounds test establishes the existence of a long-run relationship. These results provide a strong foundation for estimating the long-run impact of energy transition and climate change on economic growth and interpreting the short-run adjustments using the error correction model (ECM).

Table No. 3: ***ARDL Bound Test Results***

Test Statistic	**Value**	
F-statistic	6.458	
Critical Value Bound		
Significance	**I0 Bound**	**I1 Bound**
10%	2.08	3.08
5%	2.62	3.79
1%	3.74	5.06

Source: Authors own Estimation

4.3. ARDL Long-Run and Short-Run Test Results

The ARDL estimation results, reported in Table 4 and Table 5, delineate the long run and short run relationships, between industrial production and the explanatory variables, including climate resilience, climate vulnerability.

The long-run ARDL estimates offer much information on dynamic relations among energy transition, CO_2 emission, population growth, trade openness, energy intensity, and economic growth in Pakistan. The findings show that the growth in the economies is profoundly and positively affected by energy transition, and the coefficient of energy transition

POLICY JOURNAL OF SOCIAL SCIENCE REVIEW
PJSSR
HTTPS://JOURNALOFSOCIALSCIENCEREVIEW.COM/INDEX.PHP/PJSSR

Policy Journal of Social Science Review

Online ISSN 3006-4635
Print ISSN 3006-4627

Vol. 3 No. 12 (2025)

is 0.328 significant at the level of 1%. It means that a 1 percent change in the portion of renewable energy in the overall energy mix in Pakistan can be linked to the 0.33 percent growth in the real GDP in the long run. This observation underscores the dualism of renewable energy in supporting not only viable economic growth but also environmental safety. The beneficial impact will probably be because of various channels among them being the decreased reliance on importation of fossil fuels, energy security, and the generation of new jobs in the renewable energy sector. The findings of these studies are in line with global and regional research that indicated that clean energy investment not only generates economic processes but also limits the environmental risks. Conversely, the impact of the CO_2 emission on the long-run economic growth is a substantial negative term and the coefficient is = -0.412 at 1 percent significance level. This implies that increment in carbon emissions, which are majorly occasioned by the use of fossil fuels, may hamper growth in the long term through an increment in health-related expenses, lower productivity in labor, and environmental degradation. The results emphasize the significance of sustainable development approaches to the environment, such as the adoption of cleaner energy and tight control of emissions, in order not to undermine sustainable development goals in Pakistan. Economic growth is positively correlated with population growth in the long-run with the coefficient of 0.158 which is significant at a level of 5%. This implies that an increasing population would help in the growth of the economy by increasing the workforce and boosting domestic demand. Nonetheless, its impact is smaller compared to energy transition or emissions which implies that growth of people must be supported by investments in education, skills and infrastructure to be fruitful and viable. There is also a positive impact of trade openness on long-run economic growth with a coefficient of 0.092 significantly 10. This means that as one integrates more with the global markets, they are able to access foreign technology, capital and markets which make them more productive and diversified. However, its influence is small in relation to energy related factors which is indicative that trade liberalization can by itself not foster sustainable growth without the background of domestic energy and environmental policies. The negative significant impact (-0.185) of energy intensity (energy use divided by a unit of GDP) shows the economic cost of inefficient use of energy. Intense energy consumption increases the production costs, decreases competitiveness, and adds to the environmental strain, supporting the necessity of energy-saving strategies as well as renewable energy usage.

Table No. 4: ***ARDL Long-Run Test Results***

Variable	Coefficient	Std. Error	Coefficient	Std. Error
lnET (Energy Transition)	0.328	0.112	2.93	0.006***
lnCO_2 (CO_2 Emissions)	-0.412	0.145	-2.84	0.007***
lnPOP (Population Growth)	0.158	0.067	2.36	0.021**
lnTRD (Trade Openness)	0.092	0.048	1.92	0.064*
lnEI (Energy Intensity)	-0.185	0.073	-2.53	0.015**
Constant	1.423	0.524	2.71	0.010**

Source: Authors own Estimation

The short-run ARDL findings offer invaluable information on the direct impacts of the variation of energy transition, CO_2 emission, population growth, trade openness, and energy intensity on the economic growth of Pakistan, in addition to displaying the adjustment dynamics towards the long-run equilibrium. The coefficient of ΔlnET (energy transition) is 0.145 and statistically significant (at the 5 percent level) indicating that even in the short-term,

Policy Journal of Social Science Review
Online ISSN Print ISSN
3006-4635 3006-4627
Vol. 3 No. 12 (2025)
POLICY JOURNAL OF SOCIAL SCIENCE REVIEW
PJSSR
HTTPS://JOURNALOFSOCIALSCIENCEREVIEW.COM/INDEX.PHP/PJSSR

shares of renewable energy increase affect GDP in a positive way. It means that policy actions that encourage the use of renewable sources, like subsidies or tax incentives or funding of the solar and wind infrastructure may lead to a relatively rapid economic stimulus, but of a lesser magnitude than its long-run impact. The beneficial short-term effect shows that the investments in renewable energy sources do not only offer the advantages of long-term sustainability but also can lead to instant economic effects in the form of job creation, the adoption of new technology, and the enhancement of the energy security. On the other hand, the coefficient of Δln CO_2 (CO_2 emissions) equals 0.210, which is negative and hence short run growth in emissions has a negative impact on the economic output. This implies that environmental degradation has direct expenses to the economy, which is probably in the form of low workers efficiency, spending on health, and production processes. The observation highlights the fact that environmental management is neither a long-term issue, nor is it a process that is not vital in ensuring that the economic performance in the near future is not jeopardized. The coefficient of 0.078 of ΔlnPOP (population growth) is significant at 10 percent meaning that population growth can slightly increase economic activity in the short term both in increasing the labor force and in driving domestic demand. Nonetheless, the magnitude is relatively small which implies that population growth alone cannot be used to spur economic gains in the short run that are significant unless it is supported by successful human capital development and infrastructure. The value of ΔlnTRD (trade openness) is positive, but not statistically significant, which implies that the short-run changes in trade do not directly convert into the quantifiable change in economic growth. This could be indicative of the time-lag of trade effects because the payoff of exports, imports, and access to foreign markets is generally beneficial over a number of years. Policymakers need to be aware that trade liberalization is significant but its immediate economic effect might be minimal unless it is accompanied by other policies like export diversification and industrial upgrading. The regression coefficient of -0.098 with a significant value of 5 percent of ΔlnEI (energy intensity) indicates that inefficient use of energy is a direct source of drag on the economy at the moment. The high-energy intensity means that the costs of production will be higher, and the energy resources will be wasted, and that the energy efficiency of the industries will lead to the creation of almost immediate output benefits and the increase in the long-term sustainability. The additional insights about the dynamics of adjusting the Pakistani economy are presented by the error corruption term (ECT -1) = -0.624 that is significant at 1 percent. The negative and significant ECT proves that a stable long-run relationship is present and any short run imbalance will be alleviated at the rate of about 62.4/per year. This comparatively fast adjustment rate implies that the economy is responsive to energy transition, emissions, population, trade, or energy intensity shocks, and is able to restore the long-run equilibrium within a period of one to two years. The ECT is therefore confirming the short run and long run estimates and emphasizing the strength of the Pakistani economy in adjusting to energy and environmental changes.

Table No. 5: ***ARDL Short-Run Test Results***

Variable	Coefficient	Std. Error	t-stat	Significance
ΔlnET	0.145	0.062	2.34	0.022**
ΔlnCO_2	-0.210	0.089	-2.36	0.021**
ΔlnPOP	0.078	0.041	1.90	0.065*
ΔlnTRD	0.046	0.029	1.59	0.117
ΔlnEI	-0.098	0.044	-2.23	0.031**
ECT(-1)	-0.624	0.102	-6.12	0.000***

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
Vol. 3 No. 12 (2025)
POLICY JOURNAL OF SOCIAL SCIENCE REVIEW
PJSSR
HTTPS://JOURNALOFSOCIALSCIENCEREVIEW.COM/INDEX.PHP/PJSSR

Source: Authors own Estimation

4.4. Diagnostic Test

The Breusch-Godfrey LM test for serial correlation indicates that the residuals are **not** autocorrelated (p-value = 0.423), confirming that the model estimates are reliable and that the assumption of independently distributed errors holds. This is crucial in time-series analysis to avoid biased or inefficient estimates. The Breusch-Pagan-Godfrey test for heteroskedasticity shows a p-value of 0.317, indicating constant variance of the residuals (homoskedasticity)**.** This suggests that the error term has uniform dispersion across observations, which strengthens the reliability of t-statistics and coefficient inference.

The Jarque-Bera test for normality yields a p-value of 0.289, implying that the residuals are normally distributed. Normality of residuals is essential for valid hypothesis testing and ensures that the standard errors and test statistics are meaningful. The Ramsey RESET **test** for functional form indicates that the model is correctly specified (p-value = 0.401). This implies that no relevant variables have been omitted and that the functional form used in the ARDL specification adequately captures the relationship among GDP, energy transition, CO_2 emissions, population, trade, and energy intensity.

The CUSUM and CUSUMSQ stability tests further confirm that all estimated coefficients are stable over the sample period, as the plotted statistics remain within the 5% significance bounds. This suggests that there are no structural breaks or significant parameter shifts in the model over the period 1990–2023. Stability is particularly important given Pakistan's policy changes in energy and economic reforms, as it demonstrates that the estimated long-run and short-run relationships are robust to structural changes. Overall, the diagnostic results collectively indicate that the ARDL model is well-specified**,** stable, and reliable, with no violations of key econometric assumptions such as serial correlation, heteroskedasticity, or functional misspecification. This ensures that both short-run and long-run inferences, including the impact of energy transition, CO_2 emissions, and other variables on economic growth, are credible and can inform policy decisions confidently.

Table No. 6: ***ARDL Short-Run Test Results***

Problems	Applicable Test	F-Statistics	Probabilities
Serial Correlation	Lagrange Multiplier (LM)	0.87	0.423
Functional Form	Ramsey RESET	0.95	0.401
Normality	Jarque-Bera Test	2.48	0.289
Heteroskedasticity	Breusch-Pagan-Godfrey	1.21	0.317
CUSUM and CUSUM Square		Stable	

5. Conclusion and Policy Recommendation

The paper aims to examine the dynamic association among energy transition, CO_2 emissions, population growth, trade openness, energy intensity, and economic growth in Pakistan through an ARDL bounds testing model that examines the relationship between the variables 1990 2023. The empirical study gives strong evidence that energy transition is very important in supporting sustainable economic growth in the long run and the short run. The long-run results of ARDL show that the percentage of renewable energy in the national energy mix has a strong positive effect on real GDP, which proves that investments in clean energy do not only stimulate the development of the environment but also the state of the economy through the creation of jobs, technological progress, and energy security. This observation is in line with the evidence that is afforded worldwide, indicating that nations investing in renewable energy enjoy a twofold benefit of not only boosting their growth but also reducing the environmental risks.

On the other hand, the systemic negative impact of CO_2 emissions on economic growth is an expression of the economic cost of environmental destruction and the use of fossil fuels. Excessive amount of carbon emissions may also lower the productivity of labor, raise health related costs and increase the cost of production, thus interfering with the short run and long run growth. The research shows that there is an urgent necessity to make policies controlling the emission and promoting the cleaner production methods in Pakistan. The energy intensity, which measures the efficiency of the use of energy in relation to the amount of GDP, is determined to have a negative effect on the economic performance. The presence of high energy intensity implies ineffective use of energy which translates to high costs of production and low competitiveness. This is why the increase in energy efficiency is not only necessary due to environmental issues, but also to continue economic development. The effect of population growth on GDP is positive, although with a lesser effect, and therefore, it is arguable that a growing population can be used positively to drive the economic activity provided it is properly utilized by developing skills and investing in infrastructure. Trade openness also alters positively, but with a short-term limited impact, showing that becoming a member of the global markets can positive growth in that they allow access to capital, technology and foreign markets, but this process needs to be accompanied by domestic policy to realize the full impact into economic benefits.

Short-run ARDL findings indicate that the variations in energy transition and CO_2 emissions are directly related to the economic growth, whereas population growth and energy intensity influence the GDP, but the impact is not so strong. The error correction term (ECT) shows that there is rather a quick adjustment process with about 62 percent of long-run equilibrium deviations having been rectified within a year. It means that Pakistani economy is rather efficient in response to the shock in energy policy, environmental conditions, and other structural variables, which slowly restores long-run stability. All of these findings indicate that both short-term energy transition and environmental policies and long-term policies are essential in the establishment of a resilient and sustainable economic growth. The diagnostic tests prove the ARDL model to be stable, reliable and well-specified. The assumptions made are that the residuals are homoscedastic and distributed normally and not serially correlated, the CUSUM test and the CUSUMSQ test show that the parameters are stable during the sample period. These findings support the validity of the empirical results and justify the validity of the short-run and long-run inferences. The research hence gives a solid basis on making policy suggestions to improve the growth trend of Pakistan in connection to solving the compelling environmental and energy issues.

Concerning policy implications, the research highlights that one of the major priorities should be to speed up the implementation of renewable energy. Policymakers ought to come up with incentives in terms of tax breaks or subsidies or public-private partnerships to make investments in solar, wind, hydropower and other clean energy technologies. By increasing the renewable energy infrastructures, the country will not only be contributing to the economic growth but also decreasing the reliance on foreign fossil fuels, increasing the energy security, and decreasing the adverse effects of the climate change. In addition to the adoption of renewable energy, there is a necessity to enhance the gains of energy efficiency in industries, the commercial sector, and even homes. Modern technologies that are energy efficient, the imposition of standards regarding energy consumption and creation of awareness of energy saving should be encouraged by policies. Decreasing the intensity of energy will have a direct positive influence on the productivity, decrease the cost of production, and help to sustain the environment, resulting in a more competitive economy.

It is also essential to control the emissions of CO_2. The government is advised to introduce strict environmental policies against large polluters of the environment, encourage low-carbon technologies and invest in city planning to minimize transportation that consumes a lot of energy. The environmental concerns incorporated into the economic planning will make sure that the growth is not at the expense of the environmental degradation. Furthermore, by strengthening green finance and carbon trading systems, firms can be given a financial incentive to use cleaner technologies as well as towards sustainable development objectives. The importance of energy and environmental factors cannot be underrated, but population growth and trade openness should be managed strategically. Education, vocational training and other policies that focus on the development of human capital such as health infrastructure will enable the growing population to participate positively in the economic productivity. Equally, trade policies must not only emphasize on liberalizing trade but also on propagation of value-added exports, technology transfer, and industrial upgrading so that the openness in trade corresponds to long term economic gains. Moreover, energy and environmental policies should be incorporated in the trade and industrial strategies thus the synergistic effect can be achieved whereby the growth, sustainability and competitiveness will be reinforced by one another.

The results are also indicative of the fact that immediate results can be achieved in short-term interventions, but planning is important in the long run. The policymakers need to look ahead is the demand of energy, changes in technology, and climate risks, whereby they establish flexible and adaptive policies that would respond to changing conditions. The implementation of such comprehensive strategies will require coordination of the federal and provincial governments with the involvement of the private sector and the civil society. Finally, this paper points out that the economic development in Pakistan is closely connected with the energy and environmental promotion. Energy transition is a major source of long-term growth, and CO_2 and high energy intensity are crucial limitations. The population growth and trade openness offer another support that is conditional to the complementary policy actions. The findings emphasize the fact that sustainable growth is attainable by a concerted emphasis on the adoption of renewable energy, effective energy consumption, management of the environment, human capital development and trade policies. By adopting such recommendations, Pakistan will have the opportunity of following a growth path that is not only economical but also sustainable to the environment which in the long-term can not only improve the livelihood of the population but also the strength of the economy.

References

Abbas, S. J., Hussain, M. M., Salman, M., Shahid, S., & Iqbal, A. (2022). Economic growth, energy consumption and environment relationship: A panel data analysis of south Asian countries. *Journal of Policy Research*, *8*(4), 143-151.

Abbasi, K., Jiao, Z., Shahbaz, M., & Khan, A. (2020). Asymmetric impact of renewable and non-renewable energy on economic growth in Pakistan: New evidence from a nonlinear analysis. *Energy Exploration & Exploitation*, *38*(5), 1946-1967.

Ali, I., Malik, M. S., Iqbal, V., & Ain, Q. U. (2025). The FDI-Trade-Growth Nexus in Pakistan: A Systematic Review of the Empirical and Theoretical Literature. *Available at SSRN 5533679*.

Ali, W., Gohar, R., Chang, B. H., & Wong, W. K. (2022). Revisiting the impacts of globalization, renewable energy consumption, and economic growth on environmental quality in South Asia. *Advances in Decision Sciences*, *26*(3), 1-23.

Asghar, N., Amjad, M. A., & ur Rehman, H. (2023). An Asymmetric Analysis of Renewable Energy in Mitigating Carbon Emissions in Pakistan. *iRASD Journal of Economics*, *5*(3), 713-724.

Breusch, T.S. (1978), Testing for autocorrelation in dynamic linear models. Australian Economic Papers, 17(31), 334-355.

Breusch, T.S., Pagan, A.R. (1979), A simple test for heteroskedasticity and random coefficient variation.Econometrica: Journal of the Econometric Society, 45, 1287-1294.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. Econometrica: journal of the Econometric Society, 251-276.

Godfrey, L. G. (1978). Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables. Econometrica: Journal of the Econometric Society, 1293-1301.

Hussain, M. H., Asif, M., Khan, A. W., Ahmad, E., & Shabeer, M. G. (2025). Energy transition in an urbanizing world: Long-run drivers of CO_2 emissions in 77 emerging and developing economies. *Dialogue Social Science Review (DSSR)*, *3*(11), 1-21.

Iqbal, S., Zada, M., Naseem, H. I., & Zeb, J. (2025). Sustainable development in Asian countries: exploring the nexus between economic growth and environmental sustainability. *Clean Technologies and Environmental Policy*, *27*(9), 4611-4622.

Kashif, R., Mughal, K. M., & Gillani, D. Q. (2025). Analysis of Green Energy on Environmental Sustainability Framework in Pakistan. *Journal of Economic Impact*, *7*(3), 191-201.

Khan, M. K., Khan, M. I., & Rehan, M. (2020). The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. *Financial innovation*, *6*(1), 1.

Khan, M. K., Khan, M. I., & Rehan, M. (2020). The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. *Financial innovation*, *6*(1), 1.

Mukhtar, M., Abdulqadir, I. A., & Abubakar, H. S. (2025). Renewable Energy Transition and Sustainable Economic Growth in South Asia: Insights from the CO2 Emissions Policy Threshold. *Sustainability*, *17*(20), 9289.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, 16(3), 289-326.

Ramsey, J. B. (1969). Tests for specification errors in classical linear least-squares regression analysis. Journal of the Royal Statistical Society Series B: Statistical Methodology, 31(2), 350-371.

Raza, M. Y., & Cucculelli, M. (2024). Sustainable energy changeover in Pakistan: prospects, progress, and policies. *Environmental Science and Pollution Research*, *31*(5), 6610-6627.

Saeed, S., & Gardezi, M. A. (2025). Analyzing The Nexus Between Green Energy, Natural Resources, and Poverty Alleviation In Pakistan. *Research Journal for Social Affairs*, *3*(3), 251-263.

Yasin, R., Liaquat, M., & Safdar, N. (2024). The Role of Renewable Energy, Human Capital, and Carbon Emissions in Driving Economic Growth among South Asian Countries. *Qlantic Journal of Social Sciences*, *5*(3), 191-199.