Advance Journal of Econometrics and Finance
Vol-4, Issue-2, 2026

Advance Journal of Econometrics and Finance

Online ISSN
2959-8990
Print ISSN
2959-8982
https://ajeaf.com/index.php/Journal/About

Name of Publisher: SCHOLAR CRAFT EDUCATION & RESEARCH HUB
Review Type: Double Blind Peer Review
Journal Frequency: Quarterly Research Journal (4- Issue)

Financial Development, Renewable Energy, and CO_2 Emissions: A Method of Moments Quantile Regression Analysis of Next-11 Countries

*[1]Dr. Sheeba Zafar (CA), [2]Dr. Aqeel Ahmed, [3]Dr. Safia Begum, [4]Jawad Ali Shah

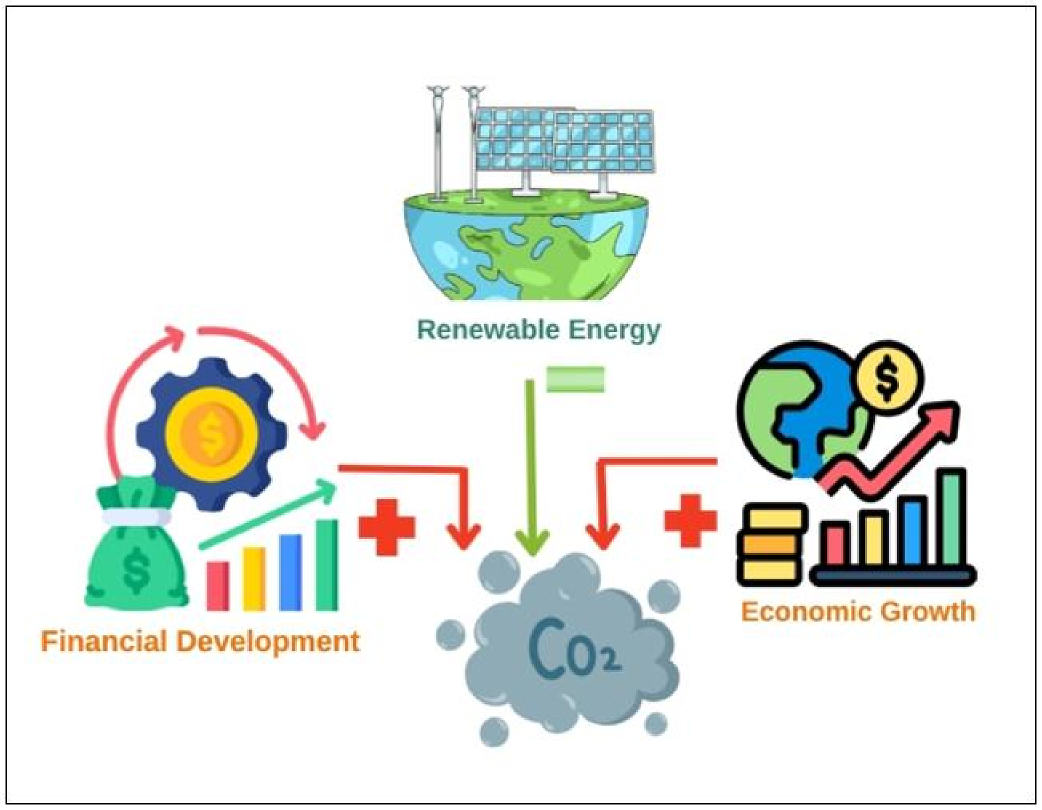
Dr. Sheeba Zafar* (CA)
Assistant Professor, Management Sciences, Shifa Tameer-e-Millat University, Islamabad, Pakistan. Corresponding Author Email: sheebazafar.dms@stmu.edu.pk
Dr. Aqeel Ahmed
Department of Economics, The Islamia University of Bahawalpur. aqeelahmed.iub18@gmail.com
Dr. Safia Begum
Associate Professor of Economics at Higher Education Department, KP, Pakistan. safiakakakhail@gmail.com
Jawad Ali Shah
Department of Economics Comsats University Islamabad. jawadalishah41@gmail.com

Abstract

The paper examines environmental degradation in Next-11 economies using the MM-Quantile Regression approach to examine the interplay among renewable energy consumption (REC), financial development (FD), economic growth (GDP) and CO2 emissions over the period 2000-2024. The findings reveal a long-run association between the study variables. The findings indicate that REC significantly reduces CO2 emissions, whereas GDP and FD enhance emissions. Evidence of distributional heterogeneity is observed. To ensure robustness, the FGLS model is used to evaluate the reliability and consistency of the main model. The MMQR findings show that the impact of REC on CO2 emissions is negative and statistically significant across all quantiles, with a stronger mitigating effect at higher-emission levels. In contrast, FD increases emissions across the distribution, but its effect diminishes at higher quantiles. Likewise, the positive and significant impact of GDP on CO2 decline as quantiles move from lower to higher. The study's outcomes suggest that REC plays an essential role in enhancing environmental quality, while FD and GDP in Next-11 countries remain closely linked with carbon-intensive development.

Keywords: CO_2 emissions; renewable energy; MMQR; Financial development; Next-11 countries

Graphical Abstract



1. Introduction

The shift in energy transition, environmental sustainability, and climate policy has emerged as a key theme in debates in all types of economies. The ever-growing emissions of carbon dioxide (CO2) have raised concerns about climate change, environmental pollution, and the sustainability of growth models based on the extensive production and consumption of fossil fuels. In this context, RE has gained significant attention as a strategic tool for enhancing environmental quality and sustaining economic activity. Simultaneously, the extent to which nations can develop renewable energy systems does not rest only on resource endowment and technological development, but also on the productivity, effectiveness, and accessibility of financial systems. The interconnection among REC, FD, GDP, and CO2 emissions is a significant concern for nations that need to grow without intensifying environmental pressures (Basheer et al., 2024).

Furthermore, these variables do not have direct connections. Financial development can facilitate the environmental drive by growing capital, mobilizing savings, distributing risk, and financing cleaner technologies, green infrastructure, and RE projects. Financial frameworks can support the deployment of renewable energy and moderate emissions (Basheer et al., 2024; Xu et al., 2023; Qayyum et al., 2021; Kim & Park, 2015; Ahmad et al., 2026; Khan et al., 2023). Instead, financial growth can also drive carbon-intensive output, boost household demand for energy-intensive products, and subsidize industrial activity, placing more pressure on the environment. World panels, Belt and Road economies, the East and South Asian regions, and the developed and emerging countries have evidence that financial development tends to increase CO2 emissions when the growth of credit has been associated with reliance on fossil energy, lax regulation, or inefficient resource allocation (Shahid et al., 2025; Ullah et al., 2023; Batool et al., 2022; Habiba & Xinbang, 2022; Sheraz et al., 2021; Khan et al., 2020; Gul et al., 2026). These contrasting outcomes recommend that the environmental role of finance is not homogeneous. There is considerable evidence that increased use of renewable sources leads to improved environmental performance through reduced carbon intensity and minimized reliance on conventional fuels. This trend has been observed in studies on India, BRICS, East and South Asia, N-5 Asian economies, and large global panels (Xu et al., 2023; Batool et al., 2022; Baskaya et al., 2022; Qayyum et al., 2021; Khan et al., 2020 Gul et al., 2020; Ikram & Gul, 2024). However, other studies describe smaller, insignificant, or even negative effects in certain environments, particularly where renewable energy is yet to be widespread, fossil fuels still control the energy-mix, or institutional and financial frameworks cannot enable efficient, large-scale renewable investments. The ambivalent empirical track record suggests that the environmental value of renewable energy.

The fact that heterogeneity defines the finance-energy-environment nexus is also emphasized in the recent literature. Indicatively, worldwide studies have shown that financial growth can enable emissions growth at certain quantiles and facilitate renewable energy growth (Jamal et al., 2024; Safdar et al., 2026; Somoye et al., 2023; Khan et al., 2020). It implies that mean-based estimators may mask significant distributional discrepancies, providing incomplete policy information. The main objective of this study: to investigate the long run relationship among the input and output variables.

This research extends the existing literature. First, it extends the research evidence on the environmental impact of FD and REC to the Next-11 economies, which remain relatively underexplored in this context. Second, it goes beyond average effects by utilizing MMQR, which can account for distributional heterogeneity that other estimators cannot. Third, it offers a comparative lens that explains why finance is a force for green transition or a cause of environmental degradation, depending on the level of emissions. By doing so, the study provides a more sophisticated foundation for policymaking, particularly for governments seeking to increase renewable energy without allowing financial deepening to entrench carbon-intensive development trends.

2. Literature Review

Many studies have examined the interrelationships among REC, FD, GDP, and environmental quality. Financial development is usually associated with greater credit availability, improved industrialization, and higher consumption, which, in turn, lead to higher energy demand. Many studies have found that CO2 emissions increase with economic expansion, especially in developing economies, where production systems are largely fossil-fuel-based. "Sheraz et al, (2021) and Batool et al., (2022), explored that FD encourages economic activity and energy consumption, rising emissions. According to Habiba and Xinbang, (2022), stated that the development of higher income levels in the early stages is typically associated with industrial growth and, hence, high energy use causes to the higher CO2 emissions. Similarly, in developing economies economic growth contributes to CO2-emissions, because green technologies are not yet fully implemented (Zafar et al., 2024; Riaz et al., 2024; Xu et al., 2023; Baskaya et al., 2022 Gul and Khan, 2021; Akhtar et al., 2020). Despite the EKC curve suggested that emissions can fall at a specific income level, most developing countries have yet to turn the corner. Conversely, many studies provide evidence that REC reduced emissions by shifting for carbon-intensive energy sources. Awosusi et al. (2022), Qayyum et al. (2021) and Khan et al. (2020) investigated that in various countries RE significantly reduced emissions. Likewise, vein, Xu et al. (2023) examined that short and long-run renewable energy enhance environmental quality, while FD and GDP improve carbon emissions. Furthermore, recent research suggested that the impact of GDP and energy-related aspects on environmental-quality varied across countries with different emission levels. Conventional means-based estimation methods rarely account for heterogeneity in CO2 emission dispersion, Because MM-Quantile regression, methods based on quantiles attracted interest for their ability to provide more detailed information." Empirical studies have shown that the effect of FD and REC fluctuates across low-, middle-, and high-emission countries. Khan et al. (2020) showed that RE consistently lowers emissions across quantiles, but the magnitude of the reduction varies with emission levels. Moreover, FD and REC have a greater impact on emissions at the highest emission quantile (Gul and Khan, 2021; Akhtar et al., 2020; Muhammad et al., 2025; Fatima et al., 2023; Somoye et al., 2023). Similarly, the quantile dependence of GDP on emissions may also differ. In low-emission economies, economic growth may exert a limited environmental impact.

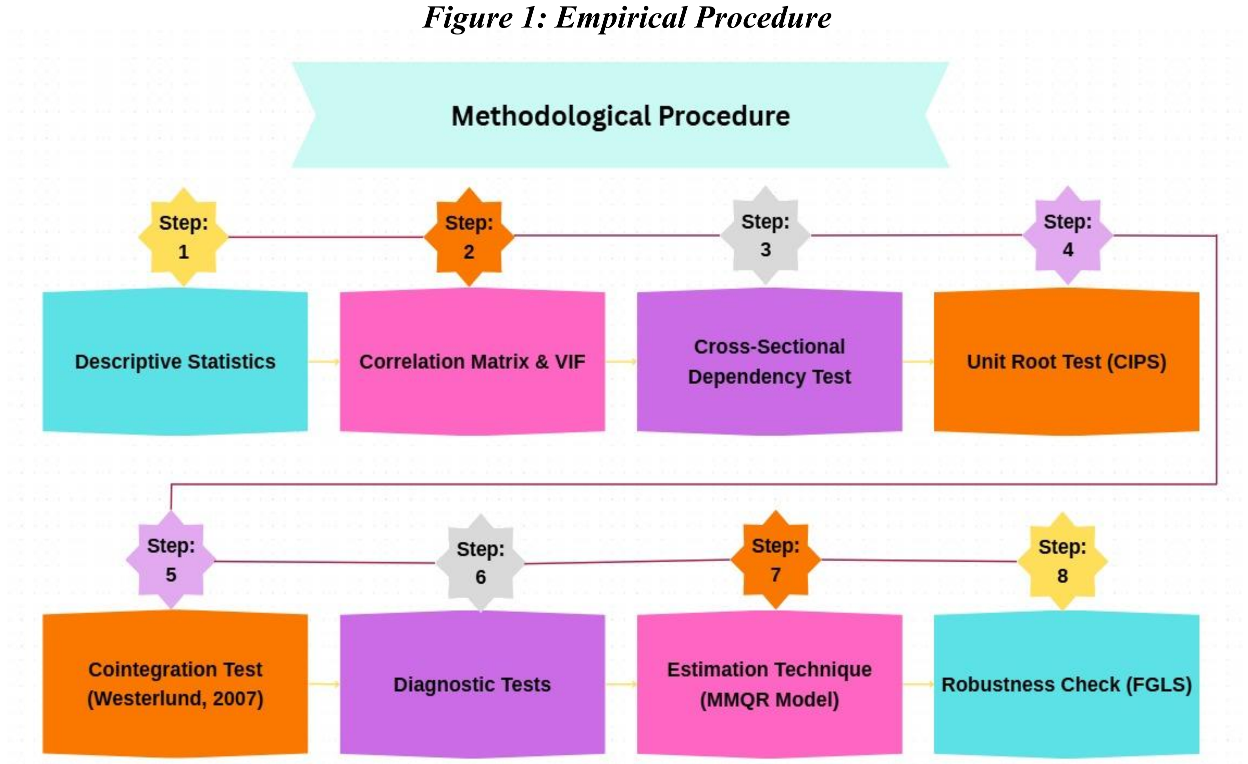
In contrast, in high-emission economies, economic growth significantly worsens environmental degradation through energy-intensive production structures. Xu et al. (2023) found that the interplay among GDP, FD, and REC is intricate and varies across countries depending on their emission levels. These results suggest that studying average effects can mask significant distributional processes. Thus, analyzing the heterogeneous effects of emission quantiles provided a more nuanced picture of the interconnections among FD, REC, GDP, and CO2 emissions. Building on this argument, the hypothesis follows:

3. Methodology

3.1 Empirical Strategy

The empirical process follows a step-by-step format. To begin with, summary statistics are used to summarize the key characteristics of the data and variables, followed by correlation and VIF to examine relationships and assess multicollinearity. Next, the CSD test was conducted to assess CSD within the panel. Considering the presence of CSD, the 2nd-generation unit root test, namely the CIPS test, is employed. After that, the Weterlund (2007) test is applied to confirm the long-run association. Diagnostic tests are then used to ensure the model's stability. The MMQR model is used as the main estimator to analyses the impacts across various quantiles. Finally, FGLS are conducted to check robustness and confirm the model consistency and reliability. Note: **Figure 1** displays the methodological procedure step by step.

Figure 1: Empirical Procedure



3.2 Data, Variables, and Measurement

This paper examines how REC, FD and GDP affect carbon emissions, using MMQR regression approach. The analysis is based on a balanced panel dataset of N11 countries spanning 2000-2024. In this framework CO2 is dependent variable, while REC, FD, GDP are key independent variables. Specifically, the CO2 emissions, are transformed into their natural logarithm (lnCO2). The input variables are: renewable energy consumption (RE_{it}), financial development (FD_{it}), while GDP per capita (GDP_{pcit}). Moreover, the logarithmic specification allows the projected coefficients to be construed as elasticities or semi-elasticities, dependent on the model description.

The functional relationship can be expressed as:

$$lnCO2 = f(RE, FD, GDPpc)$$

After logarithmic transformation of selected variables, the **empirical** form becomes:

$$\ln CO2_{it} = f\left(RE_{it}, FD_{it}, GDP_{pcit}\right)$$

Where i and t shows the country and time, respectively.

3.3 Model Specification

To investigate the interplay among the study variables to follow linear panel specification:

$$\ln CO2_{it} = \beta_0 + \beta_1 RE_{it} + \beta_2 FD_{it} + \beta_3 GDP_{it} + \varepsilon_{it}$$

Where, β_0 and $\beta_1 - \beta_3$ are indicates intercept and slope respectively, and ε_{it} is the error term.

3.4. MMQR Approach

The main model of this study is specified to examine how renewable energy, FD and GDP growth affect carbon emissions, employed MMQR developed by Machado and Silva (2019). The aims to used MMQR model because its allows the effects of explanatory variables to vary across diverse quantiles on the dependent variable, capturing distributional heterogeneity.

The quantile regression framework models the τ-th conditional quantile of the dependent variable as:

$$Q_{Y_{it}}(\tau | X_{it}) = X_{it}'\beta(\tau)$$

Where $\tau \in (0,1)$ denotes the quantile level.

Unlike standard quantile regression, MMQR allows the conditional distribution to vary through both location and scale effects. The general representation is:

$$Y_{it} = X_{it}'\beta + \sigma(X_{it})u_{it}$$

Where $X_{it}'\beta$ captures the location effect, $\sigma(X_{it})$ captures the scale effect, and u_{it} is the standardized disturbance term. The corresponding conditional quantile function becomes:

$$Q_{Y_{it}}(\tau|X_{it}) = X_{it}{}'\beta + \sigma(X_{it})q(\tau)$$

Where $q(\tau)$ is the τ-th quantile of the error distribution.

For this study, the MMQR specification is:

$$Q_{\ln CO2_{it}}(\tau|X_{it}) = \alpha_i + \beta_1(\tau)RE_{it} + \beta_2(\tau)FD_{it} + \beta_3(\tau)\ln GDP_{it}$$

This model is estimated for multiple quantiles.

4. Results and Discussion

Table 1: ***Summary Statistics And Correlation Matrix***

Variables	**Summary Statistics**				**Correlation Matrix**			
	Mean	**Std. Dev.**	**Min**	**Max**	**lnCO2**	**RE**	**FD**	**GDPpc**
lnCO2	.728	1.02	-1.433	2.58	1.000			
RE	27.00	23.858	.5	88.1	-0.815	1.000		
FD	46.93	34.932	7.923	163.516	0.626	-0.48	1.000	
GDPpc	26.79	.737	25.198	28.282	0.713	-0.45	0.353	1.000
Multicollinearity Test [VIF]								
	VIF	1/VIF						
RE	1.48	0.676						
FD	1.346	0.743	No Multicollinearity Exist					
GDPpc	1.295	0.772						
Mean	1.373	-						

Table 1 displays descriptive statistics which show a significant difference across the N11 countries. InCO2 Means and SD are 0.728 and 1.02, respectively. The Renewable energy means is 27.007, and the SD is 23.858, indicating substantial variation in its use among the sample. Financial development is also widely distributed, with a mean of 46.934 and a standard deviation of 34.932. The median of the GDP on a log scale is 26.792, and the standard deviation is relatively low at 0.737. Moreover, the correlation matrix reported in **Table 1**, indicating that REC have negative correlation with CO2, while FD and GDP have positive correlation. Furthermore, the VIF results reports also in **Table 1**, which indicate that multicollinearity is not a significant concern. Figure 2 shows a Scatter Plot of the correlation matrix, while Figure 3 displays the graphical outcomes of the VIF test.

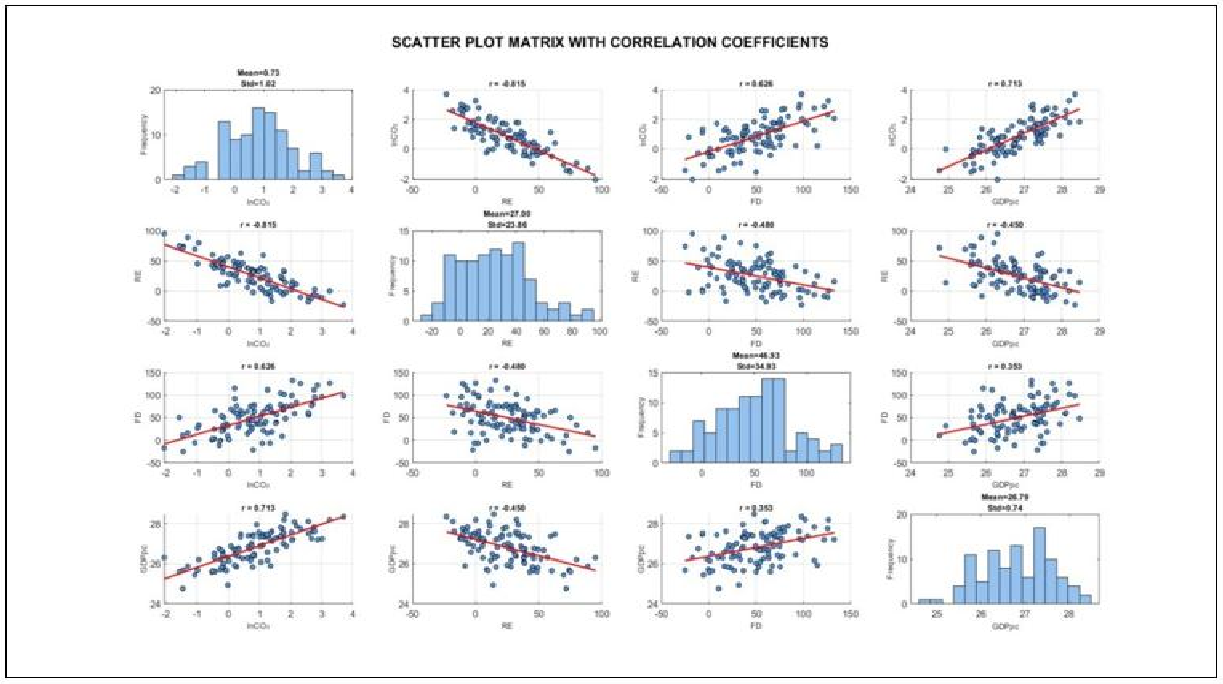


Figure 2: Scatter Plot of Correlation Matrix

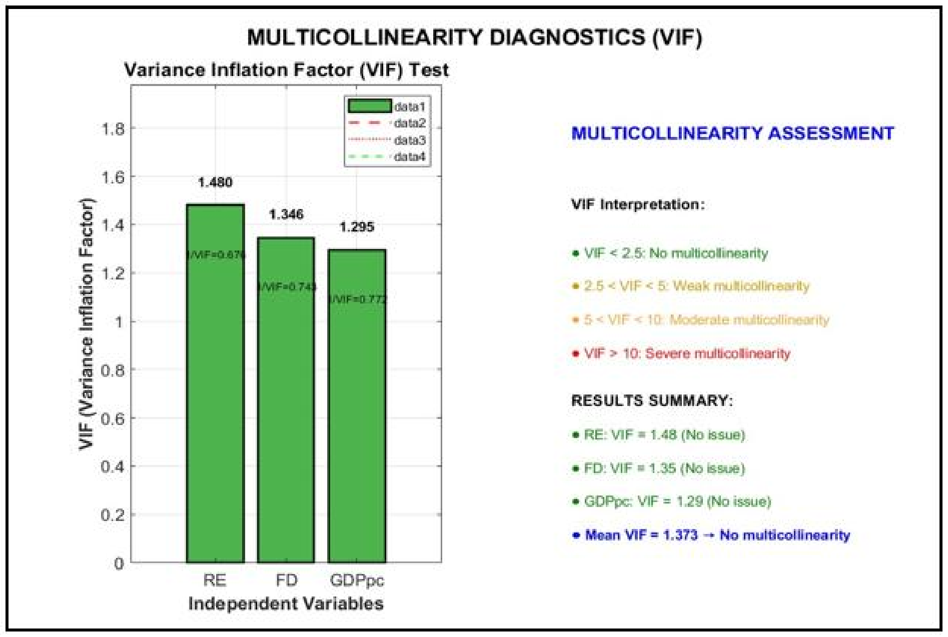


Figure 3: Multicollinearity

Table 2: ***CSD & Unit Root Tests***

Variable	CSD Test		CIPS		
	$CD_{statstics}$	P_{-value}	I(0)	I(1)	Integration order
lnCO2	11.43	0.000	-1.993	-2.934	I(1)
RE	5.86	0.000	-2.311	-3.981	I(1)
FD	6.49	0.000	-1.796	-2.792	I(1)
GDPpc	35.43	0.000	-1.733	-2.148	I(1)

Following this, **Table 2** presents the outcomes of the CSD test, indicating that CSD exists in the study panel at the 1% level. In particular, the statistics for the CD of lnCO2, renewable energy, financial development, and lnGDP are 11.43, 5.86, 6.49, and 35.43, respectively, with significance at the 1% level. So, reject the H_0. These results suggest that the Next-11 countries are not autonomous of one another. A single economic shock in a single country, e.g., an alteration in financial markets, renewable energy policy, or economic growth, can affect other countries in the panel. It is to be expected since N11 economies are intertwined.

Given this, further analysis using 2nd-generation CIPS panel unit root and cointegration approaches, presented in **Table 2,** indicates that the variables are not stationary at the level, but they become stationary after 1st differencing. The evidence specifies that the series is an order one integrated process I (1). After determining the integration order, it is necessary to test the long-run links among the variables. The Westerlund (2007) panel cointegration test is useful when CSD and heterogeneity across countries are observed; their results are displayed in **Table 3**. The results confirm the existence of a long-run relationship among the study variables.

Table 3: ***Westerlund (2007), Panel Cointegration Test***

Statistic	Value	p-value
G_τ	-4.543	0.010***
G_a	-10.209	0.672
P_τ	-6.936	0.034**
P_a	-7.473	0.745

Table 4: ***Diagnostic Test***

Wald Test	
H₀: $\sigma_i^2 = \sigma^2$ for all i (homoscedasticity)	
Test Statistic	**Value**
Chi-square ($\chi^2(11)$)	235.70
Prob > χ^2	0.0000
slope heterogeneity	
Delta	p-value
16.492	0.000
adj. 18.535***	0.000
Wooldridge test	
F(1, 10)	155.716
Prob > F	0.0000

The study considers several diagnostic tests before discussing the regression estimates. All diagnostic tests are demonstrated in Table 4. Applied three diagnostic tests first, the Modified Wald test for heteroscedasticity. The chi-square statistic is 235.70, with a p-value of 0.0000, signifying that residual variances differ across countries and that heteroscedasticity is present. Second, the slope heterogeneity test indicates that the slope is heterogeneous, not homogeneous. Third, the Wooldridge autocorrelation test confirms that autocorrelation exists in the model. All these diagnostic results suggest that the data are cross-sectional dependent, heteroscedastic, auto correlated, and slope-heterogeneous. This explains why powerful estimators like MMQR and FGLS should be used.

Table 5: ***MMQR Estimation Results***

Variables	Coefficient	SE	Z-test	[95% Interval Conf.]
location				
RE	-0.022***	0.001	-17.550	[-0.025 -0.020]
FD	0.007***	0.001	9.700	[0.005 0.008]
GDPpc	0.545***	0.041	13.190	[0.464 0.626]
Constant	-13.581***	1.122	-12.100	[-15.78 -11.381]
scale				
RE	-0.001*	0.001	-1.700	[-0.003 0.000]

FD	-0.001	0.000	-1.120	[-0.001 0.000]
GDPpc	-0.128***	0.028	-4.640	[-0.182 -0.074]
Constant	3.777***	0.749	5.050	[2.310 5.245]
Quantile1				
RE	-0.020***	0.002	-8.890	[-0.024 -0.015]
RE	0.008***	0.001	6.400	[0.005 0.010]
FD	0.784***	0.072	10.810	[0.642 0.926]
Constant	-20.656***	1.976	-10.460	[-24.528 -16.784]
Quantile2				
RE	-0.021***	0.002	-11.550	[-0.024 -0.017]
RE	0.007***	0.001	7.600	[0.006 0.009]
FD	0.700***	0.060	11.640	[0.582 0.817]
Constant	-18.163***	1.644	-11.050	[-21.385 -14.941]
Quantile3				
RE	-0.022***	0.001	-14.800	[-0.024 -0.019]
RE	0.007***	0.001	8.910	[0.006 0.009]
FD	0.619***	0.049	12.650	[0.523 0.715]
Constant	-15.783***	1.339	-11.780	[-18.408 -13.158]
Quantile4				
RE	-0.022***	0.001	-16.720	[-0.025 -0.019]
RE	0.007***	0.001	9.520	[0.006 0.008]
FD	0.573***	0.042	13.480	[0.490 0.656]
Constant	-14.413***	1.155	-12.480	[-16.676 -12.149]
Quantile5				
RE	-0.022***	0.001	-17.590	[-0.025 -0.020]
RE	0.007***	0.001	9.700	[0.005 0.008]
FD	0.546***	0.040	13.680	[0.468 0.625]
Constant	-13.627***	1.081	-12.610	[-15.745 -11.509]
Quantile6				
RE	-0.023***	0.001	-18.140	[-0.025 -0.020]
RE	0.007***	0.001	9.680	[0.005 0.008]
FD	0.516***	0.040	13.030	[0.439 0.594]
Constant	-12.738***	1.074	-11.860	[-14.843 -10.634]
Quantile7				
RE	-0.023***	0.001	-18.140	[-0.026 -0.021]
RE	0.007***	0.001	9.290	[0.005 0.008]
FD	0.477***	0.042	11.470	[0.395 0.558]
Constant	-11.568***	1.131	-10.230	[-13.785 -9.352]

Quantile8				
RE	-0.024***	0.001	-16.990	[-0.026 -0.021]
RE	0.006***	0.001	8.370	[0.005 0.008]
FD	0.430***	0.051	8.480	[0.331 0.529]
Constant	-10.187***	1.403	-7.260	[-12.937 -7.437]
Quantile9				
RE	-0.025***	0.002	-12.950	[-0.029 -0.021]
RE	0.006***	0.001	5.390	[0.004 0.008]
FD	0.290***	0.066	4.360	[0.159 0.420]
Constant	-6.042***	1.822	-3.320	[-9.614 -2.470]

Next, the MMQR results displays in **Table 5**. The location parameters represent the mean directional effect. The coefficient for renewable energy is -0.022, and its level is 1 per cent, both of which support its role in reducing emissions. Financial development has a coefficient of 0.007 and is significant at the 1 per cent level, signifying that it increases emissions. The coefficient of GDP per capita is positive and significant at 0.545. Therefore, the MMQR location effects are steady with the linear regression results. The scale equation hypothesizes the influence of the explanatory variables on the dispersion of emissions. The effect of renewable energy on the negative scale is weak, with a 10% significant negative effect, whereas GDP has a significant negative scale effect. The findings suggest that GDP not only affects the extent of emissions but also their distribution. For REC, the coefficient is negative and statistically significant at all quantiles, with values of -0.020 at the lower quantile and -0.025 at the higher quantile. Note: Figure 4 displays the graphical outcomes of the MMQR test, whereas figure 5 displays a 3D scatter plot with a spline-fitted surface.

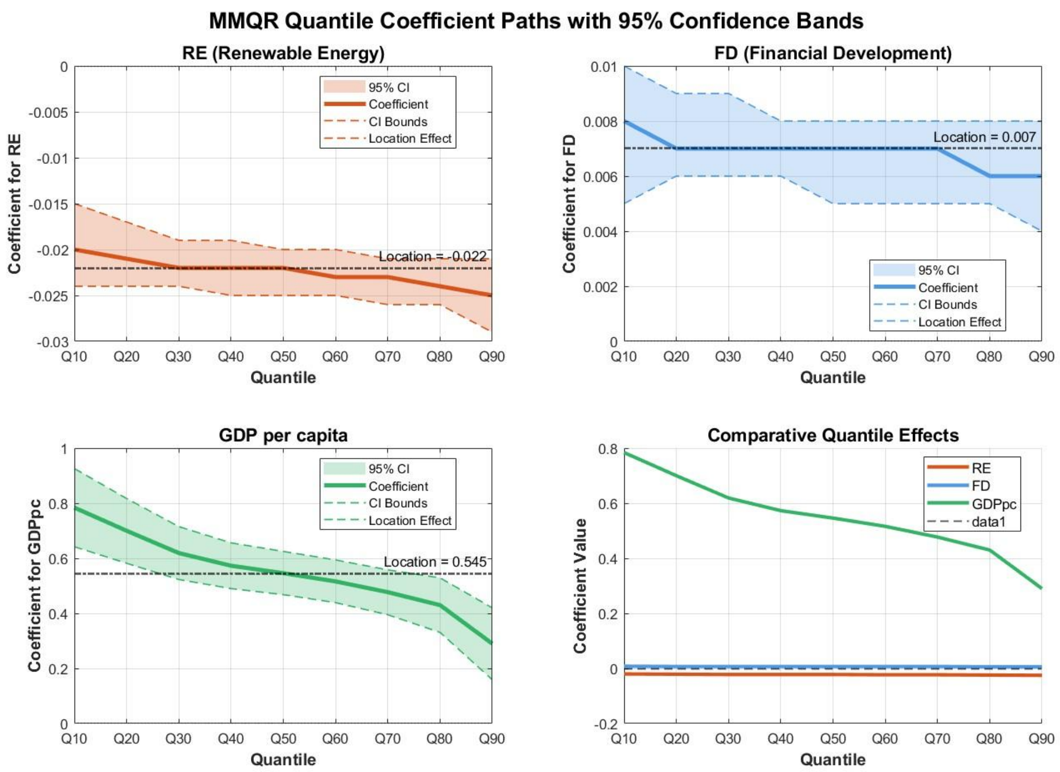


Figure 4: Graphical outcomes of the MMQR

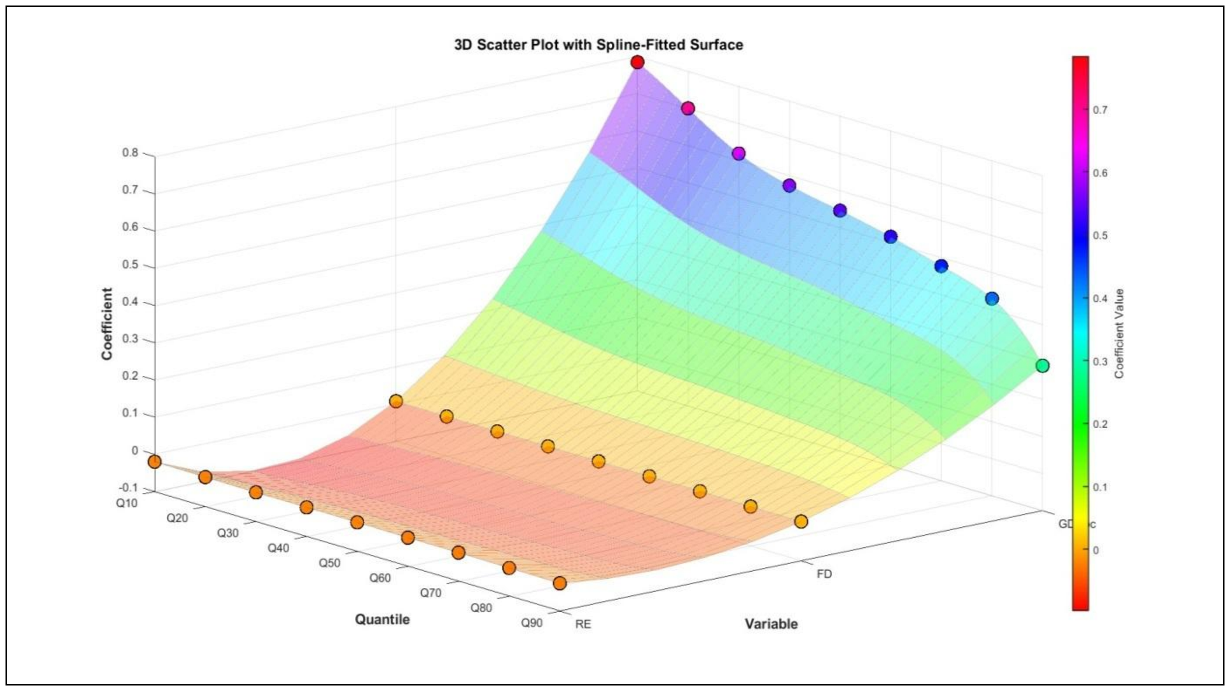


Figure 5: 3D Scatter plot

Table 6: ***FGLS Regression Results***

lnCO2	Coeff.	SE	T-value	P-value	[95% Interval Conf.]
RE	-0.022	0.002	-12.59	0.000	-0.025 -0.018
FD	0.001	0.001	2.13	0.033	0.001 0.002
GDPpc	0.417	0.043	9.76	0.000	0.333 0.500
Constant	-9.878	1.166	-8.47	0.000	-12.163 -7.593
Mean DV		0.728	SD.DV		1.020
No. of obs.		264	χ2		461.694

**** p<.01, ** p<.05, * p<.1*

Furthermore, results specify that renewable energy can always minimize carbon emissions throughout the distribution. Furthermore, the influence is marginally stronger at higher quantiles, suggesting that in high-emission countries, RE has a greater impact on reducing emissions than in low-emission countries. Policy-wise, expanding renewable energy can be particularly effective in pollution-intensive economies. In the case of financial development, the coefficient is positive and significant at all quantiles, albeit with a decreasing trend as we move to higher quantiles, from 0.008 in the lower quantile to 0.006 in the upper quantiles, indicating that improved FD leads to higher emissions during distribution. However, the impact is slightly greater in low-emission nations and slightly weaker in high-emission nations. Still, the positive indicator suggests that the financial sectors of the N11 countries remain more associated with carbon-intensive activities than with green investment. For GDP, the coefficient is positive and significant across all quantiles. However, it decreases sharply with increasing quantile, from 0.784 at the lowest to 0.290 at the highest. The results indicate that GDP has a greater emissions-enhancing impact on low-emission countries and a less significant, but positive, impact on high-emission countries. One interpretation is that even countries at the bottom of the emissions distribution may not yet have fully transitioned to high-carbon growth dynamics. In contrast, countries at the top could already have initiated partial changes by energy efficiency or cleaner production systems. The quantile outcomes clearly indicate that the impacts of REC, FD, and GDP per capita do not remain uniform across the range of emissions.

Thus, the second hypothesis can also be accepted: the effects of the explanatory variables differ across quantiles. Table 6 reports the FGLS results, which we used as a robustness check. The outcomes confirm the stability and consistency of the main model. Renewable energy, financial development and GDP per capita have negative, positive, and positive impacts of -0.022, 0.001, and positive, respectively. The coefficients are all significant, with the effect of financial development being smaller in magnitude than in the earlier models. The fact that the FGLS results are consistent with MMQR provides confidence in the empirical conclusions. The substantive interpretations have not changed even after correcting for heteroscedasticity and autocorrelation.

4.1. Discussion

In this study, we observe the dynamic relationships among FD, REC, GDP and CO2 emissions, in N11 countries using the MMQR. This evidence has been reported in previous research, indicating that renewable energy use reduces environmental degradation and supports the development of low-carbon trajectories (Qayyum et al., 2021; Wang et al., 2020; Xu et al., 2023). The quantile results also display that the alleviating effect of renewable energy increases with increasing emissions levels. It means the role of renewable energy is supplementary important in states with higher levels of pollution, a claim supported by global evidence that the adoption of renewable energy is more effective in high-emission contexts (Habiba & Xinbang, 2022; Awosusi et al., 2022; Khan et al., 2020). Thus, the outcomes support the idea that renewable energy is a major tool for achieving climate targets and sustainable development goals. Therefore, the finding is consistent with substantial literature indicating that the growth of the financial sector leads to economic activity, industrialization, and energy consumption, all of which increase emissions (Batool et al., 2022; Sheraz et al., 2021). When environmental regulations are weak and financial institutions are in place, systems are poorly developed, and financial systems often provide access to credit and investment that may stimulate growth in energy-intensive sectors. The results are consistent with those of Basheer et al. (2024), who found that financial development can reduce emissions only when it is properly linked to green energy investment and sustainability-focused financial policies. Wang et al. (2020) and Khan et al. (2021) indicated that a close connection between economic growth and environmental destruction in developing and emerging economies. When income increases, it is commonly accompanied by higher industrial production, urbanization, transportation demand, and energy consumption, which, in turn, increase emissions. The outcomes of the quantile regression, however, indicate that the effect of GDP per capita diminishes with higher quantiles, suggesting that countries with higher levels of emissions might start to experience partial gains in environmental efficiency. This trend aligns with the KEC, which shows that environmental deterioration rises in low-income countries at the early stages of development and may reverse in high-income countries after reaching a specific income level (Bilgili et al., 2021; Baskaya et al., 2022; Gul et al., 2022; Zafar et al., 2026). The interdependence of economies and the spillover effects of environmental and financial processes (Ohajionu et al., 2022; Khan et al., 2021). On the same note, the rejection of homogeneity of slopes implies that the effects of financial development, renewable energy, and GDP per capita vary across nations. This heterogeneity is unlikely to be surprising, given that the N11 group comprises countries with diverse economic systems, institutional mechanisms, and energy policies. The results of the quantile regression provide additional evidence for the second hypothesis. The impacts of renewable energy, financial development, and GDP per capita differ across points in the emissions distribution. Renewable energy continuously lowers emissions across all quantiles, with greater impacts in countries with higher emissions. The higher the financial development, the higher the emissions across all quantiles, though the growth rate is slightly lower at higher levels. The positive effect of GDP per capita is greatest at lower quantiles and weaker at higher ones. The results also align with recent work using quantile-based methods, which emphasize the importance of accounting for distributional heterogeneity in the study of environmental relationships (Awosusi et al., 2022; Basheer et al., 2024). The heterogeneous impacts of quantiles imply that the policy should not be a single model but should be country-specific, based on environmental and economic conditions."

5. Conclusion and Recommendations

This study investigates environmental degradation in Next-11 economies using the MM-Quantile Regression approach to investigate the interplay among renewable energy consumption (REC), financial development (FD), economic growth (GDP) and CO2 emissions over the period 2000 to 2024. The findings reveal a long-run relationship among the study variables. The results indicate that renewable energy significantly decreases CO2 emissions, whereas FD and GDP increase emissions. Evidence of distributional heterogeneity is observed. To ensure robustness, the FGLS model is used to assess the reliability and consistency of the main model. The MMQR findings investigate that the impact of REC on CO2 emissions is negative and statistically significant across all quantiles, with a stronger mitigating effect at higher-emission levels. In contrast, FD increases emissions across the distribution, but its effect diminishes at higher quantiles. Similarly, the positive and significant impact of GDP on CO2 decline as quantiles move from lower to higher. The paper concludes that although renewable energy is helping to curb environmental degradation, the FD and GDP in N11 countries are still not in tandem with the sustainability agenda. These results emphasize the necessity of structural and policy measures to achieve a compromise between economic and environmental growth. N11 countries are advised to increase investment in renewable energy by providing subsidies and tax exemptions, as well as cheap green financing, as these measures always reduce CO2 emissions. Green credit, green bonds and the imposition of more stringent environmental lending requirements should be used to redirect financial development towards clean industries. Economic growth policies must also focus on energy efficiency, cleaner technologies, and sustainable infrastructure, so that increased income does not further increase emissions.

6. References

1. Adebayo, T. S., Ghosh, S., Nathaniel, S., & Wada, I. (2023). Technological innovations, renewable energy, globalization, financial development, and carbon emissions: Role of inward remittances for top ten remittances receiving countries. *Environmental Science and Pollution Research, 30*, 69330–69348. https://doi.org/10.1007/s11356-023-27184-x
2. Ahmad, N., Raid, M., & Gul, A. (2026). Regional insights into poverty among women-headed households in Pakistan. *Development in Practice*, 1-10.
3. Akhtar Gul, S. H., Ali, H., & Zahra, F. (2020). COVID-19 impact on poverty and unemployment levels: A case Pakistan. *Journal of Research and Reviews in Social Sciences Pakistan*, *3*(2), 879-893.
4. Al-Zubairi, A., Al-Akheli, A., & Elfarra, B. (2025). The impact of financial development, renewable energy and political stability on carbon emissions: Sustainable development prospective for Arab economies. *Environment, Development and Sustainability, 27*, 15251–15273. https://doi.org/10.1007/s10668-024-04703-5
5. Awosusi, A. A., Adebayo, T. S., Rjoub, H., & Wong, W.-K. (2022). How do financial development and renewable energy affect consumption-based carbon emissions? *Mathematical and Computational Applications, 27*(4), 73. https://doi.org/10.3390/mca27040073
6. Basheer, M. F., Anwar, A., Hassan, S. G., Alsedrah, I. T., & Cong, P. T. (2024). Does financial sector is helpful for curbing carbon emissions through the investment in green energy projects: Evidence from MMQR approach. *Clean Technologies and Environmental Policy, 26*, 901–921. https://doi.org/10.1007/s10098-023-02659-0
7. Baskaya, M. M., Samour, A., & Tursoy, T. (2022). The financial inclusion, renewable energy and CO2 emissions nexus in the BRICS nations: New evidence based on the Method of Moments Quantile Regression. *Applied Ecology and Environmental Research, 20*(3), 2577–2595. https://doi.org/10.15666/aeer/2003_25772595
8. Batool, Z., Raza, S. M. F., Ali, S., & Abidin, S. Z. U. (2022). ICT, renewable energy, financial development, and CO2 emissions in developing countries of East and South Asia. *Environmental Science and Pollution Research, 29*, 35025–35035. https://doi.org/10.1007/s11356-022-18664-7
9. Bilgili, F., Nathaniel, S. P., Kuşkaya, S., & Kassouri, Y. (2021). Environmental pollution and energy research and development: An Environmental Kuznets Curve model through quantile simulation approach. *Environmental Science and Pollution Research, 28*, 53712–53727. https://doi.org/10.1007/s11356-021-14506-0
10. Fatima, M., Naz, S., & Khan, S. U. (2023). Energy Consumption, Economic Growth and Environmental Quality in South Asian Developing Countries: A Panel Data Analysis. *Research Journal of Social Sciences and Economics Review*, *4*(2), 244-258.
11. Gul, A., & Khan, A. W. (2021). The Effect of Small-Scale Industries on Employment Level in Pakistan. *Journal of Research and Reviews in Social Sciences Pakistan*, *4*(2), 1393-1404.
12. Gul, A., Khan, I. H., Safdar, S., & Redjil, A. (2026). Impact of Climate Change on Energy and Health: Poverty Multivariate Decomposition Analysis Using Evidence From Pakistan DHS 2012-2018. In *Advancing Climate Change Mitigation and Resilience Through Innovation and Policy* (pp. 93-124). IGI Global Scientific Publishing.
13. Gul, A., Khan, S. U., & Abbasi, R. A. (2023). Vicious circle of health expenditure: Time series evidence from Pakistan. *Journal of Contemporary Macroeconomic Issues*, *4*(1), 57-77.
14. Gul, A., Sadiq, S., & Khan, S. U. (2023). Conflicts and The Structure of Economy: A Case of Trade in Pakistan. *Journal of Development and Social Sciences*, *4*(4), 23-42.
15. Gul, A., Shabeer, M. G., Abbasi, R. A., & Khan, A. W. (2022). Africa's poverty and famines: Developmental projects of China on Africa. *Perennial journal of history*, *3*(1), 165-194.
16. Habiba, U., & Xinbang, C. (2022). The impact of financial development on CO2 emissions: New evidence from developed and emerging countries. *Environmental Science and Pollution Research, 29*, 31453–31466. https://doi.org/10.1007/s11356-022-18533-3
17. Hasni, R., Dridi, D., & Ben Jebli, M. (2023). Do financial development, financial stability and renewable energy disturb carbon emissions? Evidence from Asia–Pacific Economic Cooperation economies. *Environmental Science and Pollution Research, 30*, 83198–83213. https://doi.org/10.1007/s11356-023-28418-8
18. Ikram, N., & Gul, A. (2024). The Impact Of Conflicts On Trade: A Case Study Of Pakistan And India. *Kurdish Studies*, *12*(4), 1307-1316.
19. Jamal, F., Zhijun, Y., Khan, U. U., Zubair, M., Ahmad, S., Sultan, F., & Ullah, I. (2024). The impact of finance, infrastructure and training on the performance of SMEs in Pakistan. *South Asian J Soc Stud Econ*, *21*(4), 4.
20. Khan, A., Chenggang, Y., Hussain, J., & Kui, Z. (2021). Impact of technological innovation, financial development and foreign direct investment on renewable energy, non-renewable energy and the environment in Belt & Road Initiative countries. *Renewable Energy, 171*, 479–491.

21. Khan, H., Khan, I., & Binh, T. T. (2020). The heterogeneity of renewable energy consumption, carbon emission and financial development in the globe: A panel quantile regression approach. *Energy Reports, 6*, 859–867.
22. Khan, H., Khan, I., & Binh, T. T. (2020). The heterogeneity of renewable energy consumption, carbon emission and financial development in the globe: A panel quantile regression approach. *Energy Reports, 6*, 859–867.
23. Khan, H., Khan, I., & Binh, T. T. (2020). The heterogeneity of renewable energy consumption, carbon emission and financial development in the globe: A panel quantile regression approach. *Energy Reports, 6*, 859–867.
24. Khan, U. S., Khan, Z. M., & Gul, A. (2023). Democracy's Role in Shaping Pakistan's Economic Growth: An Empirical Evidence From Pakistan. *International Journal of Contemporary issues in social sciences*, *2*(3), 356-367.
25. Kim, J., & Park, K. (2015). Financial development and deployment of renewable energy technologies. *KAIST College of Business Working Paper Series*, KCB-WP-2015-023.
26. Muhammad, N., Khan, Z. U., Iqbal, M. A., Ullah, I., & Ahmad, N. (2025). Impact of Energy Consumption and Economic Growth on Environmental Degradation: Evidence from South Asian Countries. *Journal of Asian Development Studies*, *14*(1), 320-334.
27. Ohajionu, U. C., Gyamfi, B. A., Haseki, M. I., & Bekun, F. V. (2022). Assessing the linkage between energy consumption, financial development, tourism and environment: Evidence from method of moments quantile regression. *Environmental Science and Pollution Research, 29*, 30004–30018. https://doi.org/10.1007/s11356-021-17920-6
28. Qayyum, M., Ali, M., Nizamani, M. M., Li, S., Yu, Y., & Jahanger, A. (2021). Nexus between financial development, renewable energy consumption, technological innovations and CO2 emissions: The case of India. *Energies, 14*(15), 4505. https://doi.org/10.3390/en14154505
29. Riaz, S., Khan, S. U., Khan, A. U., & Khan, H. U. (2024). Analysing the impacts of fiscal decentralisation on public services delivery: Evidence from health sector in Pakistan. *Qlantic Journal of Social Sciences*, *5*(1), 141-157.
30. Safdar, S., Gul, A., & Khan, S. U. (2026). The Role of Green Finance in Advancing Sustainable Development: An Analysis of Financial Instruments and Their Impact on Economic and Environmental Goals. In *Green Policies for a Sustainable World* (pp. 295-330). Cham: Springer Nature Switzerland.
31. Shahid, S., Ullah, I., & Munib, F. (2025). Asian Countries Analysis on Climate Change Impact on Growth of Economy and Food Security. *Review of Economic Trends*, *2*(2), 11-21.
32. Sheraz, M., Deyi, X., Mumtaz, M. Z., & Ullah, A. (2021). Exploring the dynamic relationship between financial development, renewable energy, and carbon emissions: A new evidence from belt and road countries. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-16641-0
33. Somoye, O. A., Seraj, M., Mar'I, M., & Ozdeser, H. (2023). Quantile relationship between financial development, income, price, CO2 emissions and renewable energy consumption: Evidence from Nigeria. *Letters in Spatial and Resource Sciences, 16*, 2. https://doi.org/10.1007/s12076-023-00330-2
34. Ullah, I., Nosheen, M., Shah, K. R., & Ahmad, N. (2023). Nexus between economic growth, energy consumption and environmental degradation: empirical evidence from economic cooperation organization countries. *PAKISTAN ISLAMICUS (An International Journal of Islamic & Social Sciences)*, *3*(2), 310-334.
35. Wang, R., Mirza, N., Vasbieva, D. G., Abbas, Q., & Xiong, D. (2020). The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP21 Agreements? *Journal of Environmental Management, 271*, 111027.
36. Wang, R., Mirza, N., Vasbieva, D. G., Abbas, Q., & Xiong, D. (2020). The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP21 Agreements? *Journal of Environmental Management, 271*, 111027.
37. Xu, X., Dai, W., Muhammad, T., & Zhang, T. (2023). The dynamic relationship between carbon emissions, financial development, and renewable energy: A study of the N-5 Asian countries. *Sustainability, 15*, 13888.
38. Zafar, S., Ullah, I., Khan, K. S., & Khattak, H. (2025). Artificial Intelligence Patents and Economic Growth: A Growth Framework for OECD Countries. *Journal of Asian Development Studies*, *14*(4), 35-44.
39. Zafar, S., Akhter, T., Ahmed, A., & Ullah, I. (2026). The Green Technological Innovation-Renewable Energy-Carbon Nexus in the Big Four Emerging Economies: Evidence from Fixed-Effects Model with Driscoll–Kraay Standard Errors. *Journal of Asian Development Studies*, *15*(2), 180-190.