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Asymmetric Impacts of Financial Development, Foreign Investment, and Trade Openness on Renewable Energy Consumption in Pakistan: A Nonlinear ARDL Approach

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Abstract

The transition to renewable energy remains a critical challenge for Pakistan because of rising energy demand, financial constraints, and continued dependence on conventional energy sources. Despite growing interest in renewable energy determinants, the asymmetric transmission of economic shocks remains insufficiently explored, particularly in emerging economies such as Pakistan. The present study examines the asymmetric effects of financial development, foreign direct investment, trade openness, economic growth, and gross fixed capital formation on renewable energy consumption in Pakistan. Using annual data from 1990-2024, the study applies the Nonlinear Autoregressive Distributed Lag (NARDL) approach to investigate asymmetric short- and long-run relationships among the variables. The findings provide evidence of a stable long-run relationship between renewable energy consumption and its economic determinants. The results indicate significant asymmetric effects of financial and economic factors. Negative shocks in financial development significantly reduce renewable energy consumption, suggesting that deteriorating financial conditions may hinder renewable energy expansion. Positive foreign direct investment shocks negatively affect renewable energy consumption, indicating that foreign investment inflows may not have sufficiently supported renewable energy development. In contrast, positive changes in trade openness increase renewable energy consumption, reflecting the potential role of international integration and access to technology. Economic growth exhibits an asymmetric relationship with renewable energy consumption, suggesting that economic expansion has not yet translated into greater renewable energy adoption. The study emphasizes the importance of green finance mechanisms, environmentally oriented investment policies, and supportive trade strategies to accelerate Pakistan's renewable energy transition.

Keywords: Renewable energy consumption, Financial development, Foreign direct investment, Trade openness

JEL Classification: C22; Q42; Q43; G20; F21

1. Introduction

Pakistan faces persistent challenges in achieving a sustainable energy transition due to rising energy demand, dependence on conventional energy sources, and limited investment capacity (Asghar et al, 2023). Although the country has considerable Renewable Energy (RE) potential, particularly in solar, wind, and hydropower, financial, economic, and structural barriers constrain adoption. Understanding the economic factors that influence Renewable Energy Consumption (REC) is therefore essential for designing effective energy transition policies. REC helps reduce environmental pressures, diversify energy sources, and strengthen long-term energy sustainability. However, expanding RE depends on a wide range of economic and financial conditions, not technological availability alone. Countries' ability to increase RE utilization depends on financial resources, investment capacity, economic development, and institutional conditions that shape energy-related decisions (Danish & Ulucak, 2021; Khan et al., 2022).

Financial Development (FD) is an important pillar for expanding RE, as renewable projects require high initial investment, have long repayment periods, and need stable financing mechanisms (Benavides-Franco et al., 2023). An efficient financial system can help overcome capital limitations, expand credit availability, and enable investment in RE technologies. But this connection may not be reciprocal, since in a financial decline, barriers to renewable investment may outweigh the expected financial benefits. RE projects require significant investment, long-term financing, and strong financial frameworks. Financial system development can help ease capital constraints, facilitate financing for RE technologies, and improve access to credit. FD significantly affects REC, but the impact is mixed and depends on economic structure, institutional quality, and financial market conditions (Lahiani et al., 2021). Foreign investment can contribute to RE expansion by supporting renewable energy projects and improving technological efficiency. However, the environmental impact of FDI depends on how the investment is allocated and on sectoral preferences. In developing economies, foreign investment may also flow to energy-intensive industries, reducing the amount available for RE development (Singhania & Saini, 2021)

Trade Openness (TO) can affect RE use through technology transfer, the availability of RE equipment, and international collaboration. However, more trade may increase energy demand for industry, especially in a developing economy (Jóźwik et al., 2025). Thus, the impact of TO varies depending on the policy measures in place and the nature of the economy. Other factors that can influence the adoption of RE are Economic Growth (EG) and investment capacity within the country (Tabrizi et al., 2025). EG can provide resources for clean energy development, but growth driven by energy-intensive industries could increase dependence on conventional energy sources. Likewise, gross fixed capital formation can help realize renewable infrastructure investments if it is channeled into sustainable energy infrastructure. However, the overall impact could be higher energy demand from industries due to increased trade activity.

Economic Growth (EG) is also a major channel that impacts REC. EG can offer greater financial resources, better infrastructure capacity, and better investment opportunities for RE development. The correlation between growth and use of RE is, however, complex as in developing countries, growth can be supported by industrialization and energy-intensive processes that lead to higher reliance on traditional energy sources (Tugcu et al., 2012). Likewise, gross fixed capital formation measures domestic investment capacity and infrastructure development, both key factors that enable RE expansion. The higher the level of capital formation, the stronger the technological capacity and infrastructure availability in the field of RE, which can help support it, but investment efficiency is determined by the direction of investment, whether it is in RE or the energy-intensive economy (Gyamfi et al., 2026). Although a lot of effort has been put into identifying determinants of RE, many of the earlier studies have been based on linear econometric analysis under the assumption of a similar impact when the economic variables change positively or negatively. These assumptions can also miss critical changes in energy markets because economic booms and busts affect RE development differently. Thus, nonlinear methods are needed to capture the nonlinear response of REC to economic fluctuations. A deterioration of FD can impose greater restrictions on investment in RE than a comparable improvement of financial conditions. To overcome this drawback, (Shin et al., 2014) introduced the 'Nonlinear Autoregressive Distributed Lag (NARDL)' model that is capable of estimating the long run and short run relationships between variables in both directions, identifying positive and negative changes in the explanatory variables. Empirical research in recent years has found that FD, FDI, and TO can lead to asymmetric effects on REC, which is an argument for nonlinear modeling techniques. The empirical evidence also suggests that FD, FDI, and TO may exert asymmetric impacts on RE consumption, emphasizing the need to consider other nonlinear modeling methods (Qamruzzaman & Wei, 2020). The relationships are clearly illustrated in the case of energy security, financial constraints, and sustainable development of energy in Pakistan, as the country has been facing problems on these fronts on a regular basis.

Despite Pakistan's substantial renewable energy resources, the expansion of RE is constrained by investment shortfalls, economic uncertainty, and weaknesses in the energy sector. Although studies such as (Farooq et al., 2023) have been conducted on the energy consumption aspects of Pakistan, its impacts on economic growth and environmental consequences have received greater focus, and the asymmetric association between FD, FDI, TO, EG, and Gross Fixed Capital Formation (GFCF) and REC has received less attention. Hence, this study fills this gap by examining the asymmetric effects of FD, FDI, TO, EG, and GFCF on RE use in Pakistan. This study uses annual data from 1990 to 2024 and employs a NARDL model to analyze short- and long-term asymmetric relationships. This study offers a more in-depth understanding of the impact than is typical, as many studies assume that positive and negative changes in economic determinants have the same effect on RE use. The results offer policy insights for strengthening financial systems, improving investment allocation, and developing effective trade and energy policies to foster RE development in Pakistan.

2. Literature Review

Since FD is essential for the initiation of RE projects, its financial viability is crucial with long payback periods, and stable funding sources, financial development has been a key factor in REC. A strong financial environment can spur RE growth through a greater supply of credit, lessening credit barriers and improving capital flows toward clean energy technologies. The positive relationship between financial development and RE use is mainly manifested in enhanced financial access, green investment, and technological innovation (Le et al., 2020; Xie et al., 2022). The theory of the relationship between FD and REC, however, is still not clear. There are many conflicting views on the role of financial systems in the energy transition, ranging from the finance-led energy transition hypothesis which suggests that better financial systems are conducive to investment in renewables, to the contrary opinion that financial growth will boost energy use by stimulating economic growth and industrial development. This implies that the financial development can stimulate traditional energy-use through financial investment in traditional energy-intensive industry instead of the sustainable industry (Zhang et al., 2021). So, the relationship between financial development and its impact is related to institutional quality, financial market structure and financial allocation of investments. The other limitation of the previous studies is that they assume symmetric relationships between financial development and consumption of REN. The typical linear models have directly proportional effects. In developing economies, however, this may not be the case; financial deterioration may be the more limiting constraint on RE investments than financial improvement. Consequently, as evident in recent non-linear studies, FD can exert ‘positive and negative’ effects on RE use and it is important not to mix up positive and negative financial developments (Bibi et al., 2022).

Hence, Foreign direct investment (FDI) is an important source of external funding, technology transfer, and managerial experience. Theoretically, FDI can promote the development of RE by providing funding, new technology, foreign experts, and other support, particularly in developing countries, which have limited investment capacity (Haini, 2021). However, there is limited empirical evidence in the literature on the relationship between FDI and RE. The environmental impact of FDI is related to the nature and quality of the FDI. While FDI can help increase renewable energy generation, share the technology, and increase the chances of growth for renewable energy projects, it can also increase energy demand and environmental pressure in fossil fuel and energy-intensive industries (Doytch & Narayan, 2021). Therefore, FDI alone is not a necessarily positive factor for the consumption of renewable energy sources. Recent non-linear research also shows that foreign capital inflows could lead to asymmetric effects on energy markets: different outcomes in the energy market from increase in investment conditions than from decrease in investment conditions. Qamruzzaman and Wei (2020) show that the relationship between foreign capital flows and financial development as well as TO and REC is not always positive, in that foreign capital inflows and outflows can have differential effects on RE consumption. There is still limited country-specific evidence, however, particularly in Pakistan. This is a chance to investigate further the possible asymmetric effects of FDI on the use of RE resources.

Furthermore, there are several links between TO and REC. International trade can support the development of renewable energy by making advanced technologies, RE equipment and knowledge spillovers more available from the international market (Omri et al., 2015). Higher levels of trade integration can diminish technological obstacles and help clean energy innovations spread. But sectors' expansion can also lead to higher industrial growth and energy consumption, especially in developing countries where industries' structures are still dependent on traditional energy sources (Kaygusuz, 2012; Khan et al., 2021). Thus, the relationship between TO and RE use varies based on the structure of the economy, environmental policies, and traded goods. Empirically, results on the TO, RE nexus have been mixed in recent years, with some studies finding positive linkages and others negative (Alam & Murad, 2020; Zhang et al., 2021).

Similarly, it is well known that EG is an important determinant of energy-use patterns. Increased economic growth levels can expand financial resources, improve infrastructure development and increase the investment potential in renewables. However, this linkage between EG and RE use is multifaceted, especially in developing countries where economic development is often linked to increased industrialization and reliance on traditional energy sources (Narayan & Doytch, 2017). The relationship between energy and growth varies across countries, depending on economic structure, investment patterns, and energy policies. Gross fixed capital formation represents the investment capacity needed to develop energy infrastructure. Higher capital formation can strengthen RE deployment through infrastructure and technology development, as these technologies require high initial capital. But the effects of investment rely on the investment's direction, that is, whether into RE or energy-intensive conventional sectors (Khan et al., 2021).

3. Methodology

3.1. Data Sources and Variables

This study investigates the asymmetric effects of financial and economic determinants on renewable energy consumption in Pakistan. Although the sample consists of 35 annual observations, the NARDL framework is appropriate for small samples because it estimates short- and long-run relationships when variables are integrated at I (0) and I (1), provided none are I (2). The variables are selected based on theoretical foundations and recent empirical evidence identifying financial development, foreign capital flows, trade integration, economic growth, and investment capacity as important determinants of renewable energy development. REC is the dependent variable, 'measured as the share of renewable energy in total final energy consumption'. This indicator captures progress in renewable energy adoption and is widely used in energy transition research. The explanatory variables include FD, FDI, TO, EG, and GFCF. Renewable energy projects require large-scale financing, efficient credit allocation, and long-term investment support (Bayer et al., 2013; Polzin et al., 2019).

Financial institutions can address low levels of capital and increase financing for RE. Foreign direct investment is included as international capital flows can impact renewable energy development via technology transfer, financial investment and knowledge transfer. But foreign investment impact varies depending on the type of investment, whether converted to renewable energy or conventional energy intensive sectors (Doytch & Narayan, 2016;). In addition, TO is taken into account since the economic globalization can help to develop RE by technology transfer, access to RE equipment and international cooperation. However, there is a possibility that trade expansion could also contribute to rising energy consumption, as the economic structure and environmental policies are the factors that can influence energy demand due to the growth of the industrial sector (Chen et al., 2022). Economic growth is incorporated since the economic activity has an impact on the demand for energy, investment capacity and infrastructure development. GFCF is an indicator of domestic investment capacity and an indicator of the improvement of infrastructure, which both play a significant role in energy sector transformation and in the expansion of renewable energy systems.

Table 1: Variable Measurement

Variable	Symbol	Proxy	Source
Renewable Energy Adoption	RE	Renewable energy consumption (% total final energy consumption)	WDI
Financial Development	FD	IMF Financial Development Index	IMF
Investment	INV	Gross fixed capital formation (% GDP)	WDI
Trade Openness	TO	Trade (% GDP)	WDI
Economic Growth	EG	GDP per capita growth (%)	WDI
Foreign Direct Investment	FDI	FDI inflows (% GDP)	WDI

Note: WDI= World Development Index, IMF= International Monetary Fund

The selection of variables is conducted according to the theoretical mechanisms that are available and the empirical studies done recently on the determinants of REC. The dependent variable is REC as this shows the energy transition path and the increasing contribution of RE in the national energy system. The factors selected as explanatory variables are FD, FDI, TO, EG, and investment capacity, as they influence financial conditions, technological developments, economic expansion and infrastructure development. According to empirical evidence, financial and macroeconomic factors are significant for the adoption of RE in different economies (Le et al., 2020; Zhao et al., 2022; Wang et al., 2023).

3.2 Model Specification

The functional relationship between REC and its economic determinants is specified as:

$$REC_t = f[FD_t, FDI_t, TO_t, EG_t, INV_t] \tag{1}$$

where REC represents renewable energy consumption, FD represents financial development, FDI represents foreign direct investment, TO represents trade openness, EG represents economic growth, and INV represents a proxy for gross fixed capital formation.
The linear form of the model is expressed as:

$$REC_t = \beta_0 + \beta_1 FD_t + \beta_2 FDI_t + \beta_3 TO_t + \beta_4 EG_t + \beta_5 INV_t + \varepsilon_t \tag{2}$$

However, the linear specification assumes that positive and negative changes in explanatory variables generate identical effects. Since economic relationships may respond differently to improvements and declines, this study extends the model using the 'Nonlinear Autoregressive Distributed Lag (NARDL)' framework.

3.3. Nonlinear ARDL Framework

Following Shin et al. (2014), the NARDL model decomposes explanatory variables into positive and negative partial sums to capture asymmetric effects. Although the study uses 35 annual observations (1990–2024), the NARDL approach remains suitable because it is specifically developed for asymmetric time-series analysis and can be applied when variables are a mixture of I (0) and I (1), provided that none of the variables is integrated at I(2) (Shin et al., 2014). For each explanatory variable X, the decomposition is expressed as:

$$X_t = X_0 + X_t^+ + X_t^- \tag{3}$$

where X_t^+ and X_t^- represent positive and negative changes, respectively.
The asymmetric specification allows the study to examine whether increases and decreases in

FD, FDI, TO, EG, and GFCF affect REC differently. The general NARDL error correction representation is expressed as:

$$\Delta REC_t = \varphi\left(REC_{t-1} - \beta_0 - \beta_1 X_{t-1}\right) + \sum_{i-1}^{p} \delta_i \Delta REC_{t-1} + \sum_{j=0}^{q} \theta_j^{+} \Delta X_{t-j}^{+} \eta_t \quad (4)$$

where φ represents the Error Correction Term (ECT) indicating the speed of adjustment toward long-run equilibrium, while θ_j^{+} and θ_j^{-} represent short-run coefficients of positive and negative changes. Dynamic multipliers assess the cumulative effects of shocks over time. Dynamic multipliers illustrate the adjustment path of renewable energy consumption following positive and negative shocks in explanatory variables (Urom et al., 2012).

$$m_h^{+} = \sum_{j=o}^{h} \theta_j^{+}, m_h^{-} = \sum_{j=o}^{h} \theta_j^{-}$$

4. Results and Discussions

4.1 Preliminary Investigation

Table 1 presents the 'descriptive statistics' of the study variables. REC has the highest mean value (48.335), while economic growth has the lowest (1.611). Regarding variability, economic growth exhibits the highest standard deviation (2.096), indicating greater fluctuations during the study period, while the financial development index shows relatively lower variation with a standard deviation of 0.1499. The skewness value shows that most of the variables are fairly well distributed with a FDI having higher positive skewness signifying the fluctuations in external capital inflows. Further, the 'Jarque Bera' test results indicated that the consumption of REC, EG, FD, TO and GFCF were normally distributed, and foreign direct investment had non-normal distribution characteristics.

Table 2: Descriptive Statistics of Variables

Statistics	REC	EG	FDI	FD	TO	INV
Mean	48.335	1.611	0.921	0.220	30.588	14.898
Median	47.400	1.537	0.696	0.166	30.890	14.286
Maximum	58.100	5.202	3.035	0.461	38.499	19.112
Minimum	41.600	-3.038	0.309	0.025	21.460	11.489
Std. Dev.	4.601	2.096	0.649	0.149	4.689	1.876

Skewness	0.332	-0.093	2.095	0.240	-0.090	0.502
Kurtosis	2.284	2.473	6.700	1.726	1.995	2.404
Jarque-Bera	1.388	0.456	45.570	2.704	1.5192	1.991
Probability	0.499	0.796	0.000	0.258	0.467	0.369
Observations	35	35	35	35	35	35

The trends in REC and some of the explanatory variables in Pakistan from 1990 to 2024 are shown in Figure 1. The use of RE has not been a consistent trend in Pakistan's energy structure, as it dropped gradually from nearly 58% in the early 90's to approximately 42% recently. In spite of the growing attention of policies on renewable energy, shares of RE sources have fluctuated over times, mainly due to investment constraints, energy insecurity and reliance on conventional energy sources. Financial development has relatively little variation in the study period but still, indicates a slow but still inadequate progress towards strengthening Pakistan's financial capacity for large-scale RE implementation. The level of trade openness is very volatile especially during times of macroeconomic instability and shocks that could impact technology imports and diffusion of renewable energy. Likewise, investment and FDI have also been volatile, reflecting uncertainties in capital flow and infrastructure.

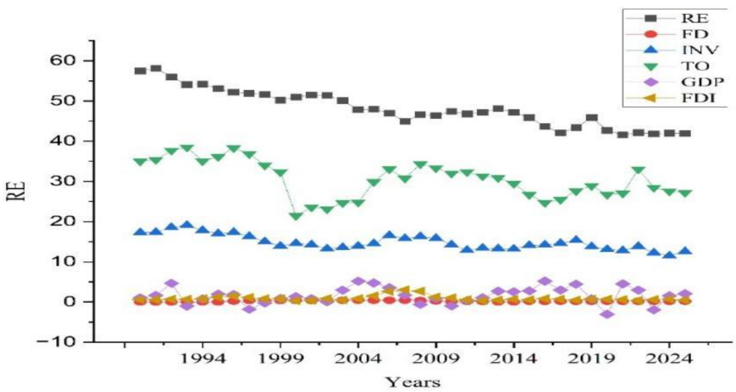

Figure 1: Evolution of renewable energy consumption and macroeconomic determinants in Pakistan (1990–2024)

Pearson correlation matrix is reported in Table 2, giving preliminary insights on the relationships among the variables. TO (0.493) and INV (0.695) are positively related with REC, suggesting that higher TO and investment capacity may facilitate the development of RE. On the other hand, RE indicates low negative relationship with economic growth (-0.119), FDI (-0.075) and FD (-0.156). There were no significant issues with 'multicollinearity' because the correlation coefficients between the explanatory variables were within the permitted range.

Table 3: Correlation Matrix

	REC	**EG**	**FDI**	**FD**	**TO**	**INV**
REC	1.000					
EG	-0.119	1.000				
FD	-0.075	-0.013	1.000			
FDI	-0.156	0.050	0.467	1.000		
TO	0.493	-0.225	0.289	-0.368	1.000	
INV	0.695	0.001	0.319	-0.197	0.707	1.000

4.2. Unit Root Test

The unit root test findings ('ADF & Phillips-Perron') are shown in Table 3. The results indicate that the variables are level-stationary and first difference-stationary.

Table 4: Unit Root Test

Variables	**ADF**		**PP**	
	At level I/ (0)	**At Difference I/ (1)**	**At level I/ (0)**	**At Difference I (1)**
REC	-1.518 (0.512)	-5.395(0.000)	-1.771(0.387)	-6.330(0.000)
FD	-1.5799 (0.482)	-4.097(0.003)	-1.801(0.373)	-4.136(0.002)
FDI	-3.035 (0.041)	-3.974(0.004)	-1.930(0.315)	-3.840(0.006)
INV	-1.522 (0.510)	-5.140(0.000)	-1.522(0.510)	-5.143(0.000)
EG TO	-3.332 (0.022) -1.993(0.288)	-7.511(0.000) -5.971(0.000)	-4.657(0.000) -2.051(0.264)	-12.874(0.000) -5.972(0.000)

Notes: The critical significance levels are based on conventional thresholds of 1%, 5%, and 10%.

The REC, the FD and investment are non-stationary at level but become stationary after taking first differences. FDI shows mixed behavior: it is stationary at level under the ADF test but becomes stationary after first differencing under both tests. Economic growth is stationary at level, confirming its I (0) status. Since none of the variables are integrated beyond the first difference, the results confirm that the data are suitable for applying the NARDL approach.

4.3. NARDL Bound Test

Table 4 presents the results of the NARDL bounds test to examine whether a long-run relationship exists between REC and its determinants. The calculated 'F-statistic' value is 4.907, which exceeds the upper bound critical value of 3.610 at the 1% significance level. Therefore, we reject the null hypothesis of no cointegration, confirming a stable long-run relationship among the variables. This result indicates that FD, FDI, TO, EG, and INV jointly influence REC in Pakistan over the long term. The cointegration results justify applying the NARDL model to further investigate the 'asymmetric short- and long-run effects' of these economic determinants on renewable energy consumption.

Table 5: Results of NARDL cointegration bounds test.

Test Statistic	**Value**	**K (number of regressors)**
F-statistic	4.907	10
Sample size	35	
Significance Level	I (0) Lower Bound	I (1) Upper Bound
10%	1.760	2.770
5%	1.980	3.040
1%	2.410	3.610

The negative and statistically significant error correction coefficient (REC (-1) = -0.982) confirms the existence of a stable adjustment mechanism, indicating that approximately 98.2% of deviations from long-run equilibrium are corrected within one year. The quick adjustment implies high sensitivity of renewable energy use to macroeconomic shocks and a tendency towards the original path. The result is consistent with the theoretical structure of ARDL error corrective model given by Engle and Granger (1987) and elaborated by Pesaran et al. (2001) which suggests that the cointegrated variables move in a dynamic manner following short run disturbances. The evidence of strong error-correction mechanisms is also found in other energy transition studies based on ARDL and NARDL methods (Shin et al., 2014; Qamruzzaman & Jianguo, 2020). Using small samples with highly parameterized nonlinear models, especially because they can yield over-optimistic estimates of adjustment speed and require further robustness testing, such as stability and specification tests (Narayan, 2005). However, the high ECM coefficient reiterates that the long-run relationship between the renewable energy sector and macroeconomic fundamentals in Pakistan remains meaningful. The asymmetric impact of economic growth offers important insights for Pakistan's transition to renewable energy. The positive growth shock (EG = -0.605) is definitely negative, indicating that growth in the past has historically increased the use of conventional energy sources rather than increasing the use of renewable energy. The negative effects of positive shocks to growth suggest that Pakistan's economy has not experienced a structural shift in the use of renewable energy yet. This may be because growth has been associated with energy intensive activities which are still largely dependent on traditional energy sources. Therefore, if a clean tech revolution, environmental policies and sustainable infrastructure investments are not implemented, then economic growth will not be enough to ensure the transition to renewables (Apergis & Payne, 2010; Nathaniel et al., 2021). Findings in developing economy countries reveal that the first step of EG increases energy consumption as a consequence of industrialization, urbanization and manufacturing growth, but that a first increase in energy use does not necessarily lead to an increase of renewable energy production without government policy actions (Sadorsky, 2009; Omri, 2013; Apergis & Payne, 2010). EG alone is not enough for the transition towards a clean energy economy; the environmental effects of economic growth will rely on technological innovation, institutional robustness and energy policy orientation (Destek and Sarkodie, 2019). There is a heterogeneous relationship between growth and renewable energy across countries and there is a strong cross-country variation of the relationship which varies based on the level of development and the energy structure (Qamruzzaman & Jianguo, 2020; Khan et al., 2022). In this sense the negative growth effect on Pakistan indicates that in its path of economic growth, it is not experiencing the structural transformation towards a renewable-based energy system.

The contribution of financial and external sector variables further reinforces the necessity of economic growth, more financial resources for investments and integration with the outside world to achieve Pakistan's target on renewable energy transition. The negative impact of positive capital inflows (FDI-POS = -4.453) indicates that past foreign capital inflows have been detrimental to the development of renewable energy, and possibly have been targeted at traditional energy sector and carbon intensive industries. The findings run counter to the pollution-halo hypothesis which suggests that foreign investment is likely to stimulate the adoption of “clean” technologies in developing countries. The negative environmental effects of FDI are linked to the sectoral composition of FDI, regulatory quality and host country policies (Pao & Tsai, 2011; Tang & Tan, 2015; Shahbaz et al., 2018). The positive financial development (FD-POS = -3.803) is very low as enhancements in financial system in Pakistan have not contributed to the significant increase in the use of renewable energy. The result is consistent with previous research that suggests that financial depth, financial institutions, credit allocation, and environmental factors moderate the link between financial development and renewables (Bonga et al., 2026).

This could be due to the ability of green financing schemes, low financing for renewables or continued investment of financial resources on traditional energy generation. These issues imply that financial deepening cannot be seen as a driver to encourage investment in RE in Pakistan. However, the negative effect of financial deterioration (-12.364) is substantial and indicates that the financial instability is a significant challenge for the adoption of renewables, since renewable energy projects require long-term financing, low interest rates and a stable investment environment (Majeed & Hussain, 2025). The NARDL has also been applied in the literature in recent years to demonstrate that the financial-renewable energy nexus is not necessarily symmetrical, that is, positive and negative financial shocks have varying effects on renewable energy adoption (Lahiani et al., 2021, Qamruzzaman & Jianguo, 2020) Therefore, instead of the expansion of the financial sector, Pakistan should adopt specific green finance instruments.

Table 6: NARDL and FMOLS

Dependent Variable: Renewable Energy Consumption (REC)		
Variable	**NARDL Coefficient**	**FMOLS Coefficient**
EG (POS)	-0.605*** (0.170)	-0.303*** (0.0574)
EG(NEG)	0.3427* (0.180)	0.2179** (0.0782)
FDI(POS)	-4.453*** (1.170)	-2.1557*** (0.4218)
FDI(NEG)	1.461 (1.014)	0.4108 (0.5153)
FD(POS)	-3.803 (2.770)	-7.5514*** (1.6596)

FDI(NEG)	-12.364** (5.618)	-7.2870** (3.2051)
TO(POS)	0.842*** (0.268)	0.3961*** (0.1105)
TO(NEG)	-0.016 (0.072)	-0.0125 (0.0451)
INV(POS)	0.366 (0.598)	-0.4700 (0.3481)
INV(NEG)	-0.765* (0.370)	-0.5229** (0.2314)
REC(-1)	-0.982*** (0.155)	—
C	54.395*** (8.836)	56.536*** (0.3607)
D(EG)-Pos	-0.296*** (0.101)	
D(FD)-Pos	-2.819* (1.280)	
D(TO)-Pos	0.602*** (0.175)	
R-sqaure	0.87	0.970
Adjusted R-square	0.83	0.9547
Diagnostics Test		
LM Serial Correlation	F = 2.128 (0.151)	No serial correlation
JB test	4.205 (0.122)	Residuals are normally distributed
Heteroskedasticity	F = 0.781 (0.676)	No heteroskedasticity

Ramsey RESET	F = 0.531 (0.475)	Model is correctly specified

Notes: Standard errors are reported in parentheses below coefficients. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively. FMOLS estimation uses the Bartlett kernel and Newey-West fixed-bandwidth correction.

The diagnostic tests reveal that the estimated model of NARDL is statistically reliable and adequate. The 'Breusch-Godfrey serial correlation LM' test is not significant (p = 0.151), which suggests that there is no serial correlation in the residuals. This further confirms that the time dependence between the REC and those variables used to explain them is shown in the dynamic structure of the model. The non-correlated residuals are also essential in the ARDL models because correlated residuals will lead to inefficient estimates and unreliable statistical inferences (Pesaran et al., 2001; Wooldridge, 2020). The 'Jarque–Bera normality test' also shows that the residuals are normally distributed (p = 0.122), which means that the estimated coefficients and their significance tests are statistically valid. Furthermore, the 'Breusch-Pagan-Godfrey' test indicated that there was no heteroskedasticity (p = 0.676), which implies that the variance of the residuals among the observations is not different. These results agree with the classical regression analysis a priori assumptions, and validate estimated relationships. The acceptance of the diagnosis, however, does not mean full confidence in the reliability of the model, as the energy sector in Pakistan, which was subjected to diagnosis, has experienced structural change, policy changes and external shocks, which may impact parameter stability. In the end, there is still need for additional analysis of stability like 'CUSUM and CUSUMSQ' to make final decisions on policy (Brown et al., 1975; Shin et al., 2014).

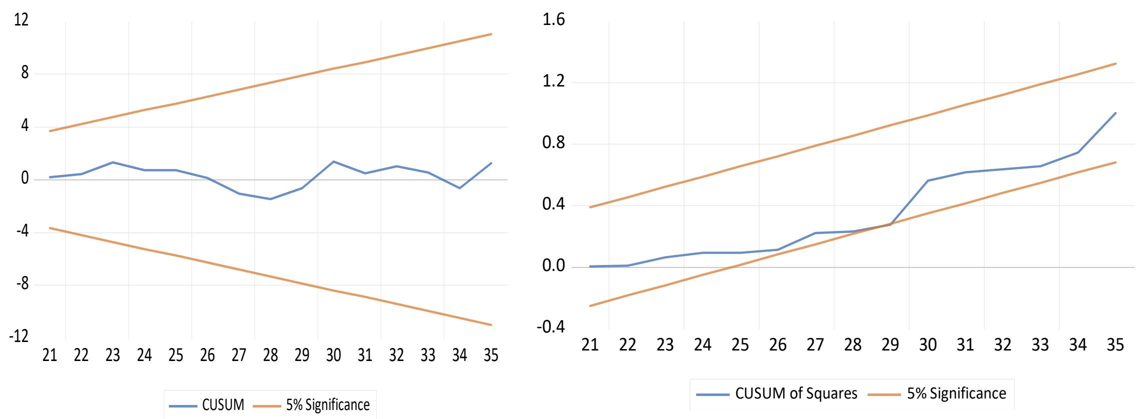

Figure 2: Model Stability Tests: CUSUM and CUSUM of Squares

5. Conclusion

The present study has employed the Non-Linear Autoregressive Distributed Lag model for analyzing the asymmetric relationship between financial development, foreign direct investment, trade openness, economic growth, gross fixed capital formation and renewable energy consumption for Pakistan during 1990-2024. The findings support the long run relationship between REC and its economic determinants, highlighting the significance of financial and macroeconomic factors for the transition towards renewables in Pakistan. The results demonstrate that the impact of positive and negative economic shocks is dissimilar on RE consumption. Financial shocks are also asymmetric: negative shocks to financial development led to a significant reduction in REC but positive shocks to FD do not lead to significant gains in renewable energy. This underscores the need for sustainable finance and specific green financing tools. Similarly, positive FDI shocks lead to a corresponding drop in renewable energy consumption, suggesting that foreign investment, overall, is not adequately focused on renewable energy. But this result should be taken with a pinch of salt as total FDI data are not broken down into renewable and non-renewable sectors. Greater openness to trade has positive impacts on REC, implying that integration with the outside world could play a role in facilitating the growth of renewable technologies and spreading of knowledge. On the other hand, positive EG shocks are associated with the reduction in the REC resources, which means that Pakistan has not yet seen a significant shift towards RE based energy systems with the economic development. Overall, the results indicate that effective energy investment allocation, supportive energy policies and environmentally oriented economic strategies are necessary, apart from economic growth and development, for shifting to renewable energy.

The study suggests some policy implications**.** First, there is a need to boost green finance mechanisms to enable the financial sector to be instrumental in promoting growth of renewable energy in Pakistan. However, financial deterioration is more harmful for the adoption of renewable energy and should be supported by policymakers through stable credit markets, low-cost financing facilities, green bonds, and dedicated renewable energy financing programs. Financial institutions should provide long-term loans to promote the use of RE, rather than conventional energy. Second, the objective of policies should be to improve the climate for FDI. Since a positive FDI shock has been found to decrease the usage of renewable energy, FDI screening mechanisms are required to attract investment in renewable energy, clean technology and sustainable infrastructure in Pakistan. Foreign investment can be promoted by providing incentives for investments in environmentally responsible activities. Thirdly, Pakistan should encourage the diffusion of renewable technologies by promoting trade liberalization. Energy importation, including renewables, should be supported by energy trade policy such as imports of energy equipment, solar panels, wind technologies, energy storage systems. Domestic renewable energy capacity can be further increased through technology-transfer and international cooperation. Fourth, economic growth policies ought to be reformed to ensure a low-carbon development pathway. Economic growth is correlated with increased consumption of traditional energy sources; that means that policies on energy, industry and economy needs to promote energy efficiency, cleaner production technologies, and integration of renewables in energy-intensive sectors experiencing growth. Fifth, sustainable infrastructure development is key to investment policies. Energy storage, grid modernization, renewable energy and transmission should be considered for gross fixed capital formation. Private sector involvement in renewable energy markets should be encouraged through public investment.

References

[1] Alam, M. M., & Murad, M. W. (2020). The impacts of economic growth, trade openness and technological progress on renewable energy use in organization for economic cooperation and development countries. *Renewable Energy, 145*, 382–390. https://doi.org/10.1016/j.renene.2019.06.054

[2] Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and growth in Eurasia. *Energy Economics, 32*(6), 1392–1397. https://doi.org/10.1016/j.eneco.2010.06.001

[3] Asghar, R., Sulaiman, M. H., Mustaffa, Z., Ullah, N., & Hassan, W. (2023). The important contribution of renewable energy technologies in overcoming Pakistan's energy crisis: Present challenges and potential opportunities. *Energy & Environment, 34*(8), 3450–3494.

[4] Bayer, P., Dolan, L., & Urpelainen, J. (2013). Global patterns of renewable energy innovation, 1990–2009. *Energy for Sustainable Development*, *17*(3), 288-295. https://doi.org/10.1016/j.esd.2013.02.003

[5] Benavides-Franco, J., Gómez, J. M., & Pérez-Uribe, M. A. (2023). Determinants of Project Finance success for renewable energy. *Renewable Energy, 211*, 188–201.

[6] Bibi, A., & Li, X. M. (2022). The asymmetric dilemma of renewable energy, financial development, and economic growth: fresh evidence from Pakistan. *Environmental Science and Pollution Research*, *29*(21), 31797-31806 .https://doi.org/10.1007/s11356-021-17914-4

[7] Bonga-Bonga, L., & Kirsten, F. (2026). Assessing the Key Mediating and Moderating Factors in the Renewable Energy Generation and Financial Institution Development Nexus Among African Economies. *Energies*, *19*(9), 2225. https://doi.org/10.3390/en19092225

[8] Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society: Series B (Methodological), 37*(2), 149–192. https://doi.org/10.1111/j.2517-6161.1975.tb01532.x

[9] Chen, S., Zhang, H., & Wang, S. (2022). Trade openness, economic growth, and energy intensity in China. *Technological Forecasting and Social Change*, *179*, 121608. https://doi.org/10.1016/j.techfore.2022.121608

[10] Danish, & Ulucak, R. (2021). A revisit to the relationship between renewable energy consumption and economic growth: Fresh evidence from nonlinear panel analysis. *Renewable Energy, 169*, 141–151. https://doi.org/10.1016/j.energy.2021.120337

[11] Demystifying pollution haven hypothesis: Role of FDI. *Journal of Business Research, 123*, 516–528. https://doi.org/10.1016/j.jbusres.2020.10.007

[12] Destek, M. A., & Sarkodie, S. A. (2019). Investigation of environmental Kuznets curve for ecological footprint: The role of energy and financial development. *Science of the Total Environment, 650*, 2483–2489 .https://doi.org/10.1016/j.scitotenv.2018.10.017

[13] Doytch, N., & Narayan, S. (2021). Does FDI influence renewable energy consumption? Evidence from emerging economies. *Energy Economics, 96*, Article 105153. https://doi.org/10.1016/j.eneco.2015.12.010

[14] Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica, 55*(2), 251–276. https://doi.org/10.2307/1913236

[15] Gyamfi, B. A., Yadav, A., Agozie, D. Q., Kumar, N., & Asongu, S. A. (2026). Financial development, infrastructure, and energy transition in developing economies. *Energy*, 142050. https://doi.org/10.1016/j.energy.2026.142050

[16] Jóźwik, B., Sarıgül, S. S., Topcu, B. A., Çetin, M., & Doğan, M. (2025). Trade openness, economic growth, capital, and financial globalization: Unveiling their impact on renewable energy consumption. *Energies, 18*(5), 1244. https://doi.org/10.3390/en18051244

[17] Kaygusuz, K. (2012). Energy for sustainable development: A case of developing countries. *Renewable and Sustainable Energy Reviews, 16*(2), 1116–1126. https://doi.org/10.1016/j.rser.2011.11.013

[18] Khan, Z., Ali, S., Umar, M., Kirikkaleli, D., & Jiao, Z. (2021). Consumption-based carbon emissions and renewable energy development: Evidence from developing economies. *Renewable Energy, 172*, 347–357.https://doi.org/10.1016/j.scitotenv.2020.138945

[19] Khan, Z., Hussain, M., Shahbaz, M., Yang, S., & Jiao, Z. (2022). Natural resource abundance, technological innovation, and renewable energy transition. *Energy Economics, 106*, 105806.https://doi.org/10.1016/j.resourpol.2020.101585

[20] Lahiani, A., Mefteh-Wali, S., Shahbaz, M., & Vo, X. V. (2021). Does financial development influence renewable energy consumption to achieve carbon neutrality in the USA? *Energy Policy, 158*, 112524. https://doi.org/10.1016/j.enpol.2021.112524

[21] Le, T. H., Chang, Y., & Park, D. (2020). Renewable and non-renewable energy consumption, economic growth and emissions: Evidence from emerging economies. *Energy Economics, 92*, Article 104935.https://doi.org/10.5547/01956574.41.2.thle

[22] Majeed, M. T., & Hussain, Z. (2025).Financial sector development and renewable energy consumption nexus: Evidence from global dynamic panel threshold analysis. *Natural Resources Forum, 49*(3), 2299–2323. https://doi.org/10.1111/1477-8947.12469

[23] Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics, 37*(17), 1979–1990. https://doi.org/10.1080/00036840500278103

[24] Narayan, S., & Doytch, N. (2017). An investigation of renewable and non-renewable energy consumption and economic growth nexus using industrial and residential energy consumption. *Energy Economics, 68*, 224–234. https://doi.org/10.1016/j.eneco.2017.09.005

[25] Omri, A. (2013). CO_2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy Economics, 40*, 657–664. https://doi.org/10.1016/j.eneco.2013.09.003

[26] Omri, A., Nguyen, D. K., & Rault, C. (2014). Causal interactions between CO2 emissions, FDI, and economic growth: Evidence from dynamic simultaneous-equation models. *Economic Modelling*, *42*, 382-389. https://doi.org/10.1016/j.econmod.2014.07.026

[27] Pao, H. T., & Tsai, C. M. (2011). Multivariate Granger causality between CO_2 emissions, energy consumption, FDI and GDP: Evidence from BRIC countries. *Energy, 36*(1), 685–693. https://doi.org/10.1016/j.energy.2010.09.041

[28] 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. https://doi.org/10.1002/jae.616

[29] Polzin, F., Egli, F., Steffen, B., & Schmidt, T. S. (2019). How do policies mobilize private finance for renewable energy? A systematic review with an investor perspective. *Applied Energy*, *236*, 1249-1268. https://doi.org/10.1002/jae.616

[30] Qamruzzaman, M., & Wei, J. (2020). The asymmetric relationship between financial development, trade openness, foreign capital flows, and renewable energy

consumption: Fresh evidence from panel NARDL investigation. *Renewable Energy, 159*, 827–842. https://doi.org/10.1016/j.renene.2020.06.069

[31] Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. *Energy Policy, 37*(10), 4021–4028. https://doi.org/10.1016/j.enpol.2009.05.003

[32] Shahbaz, M., Nasreen, S., Abbas, F., & Anis, O. (2018). Does foreign direct investment impede environmental quality in high-income countries? *Environmental Science and Pollution Research, 25*, 33226–33242. https://doi.org/10.1016/j.eneco.2015.06.014

[33] Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In R. C. Sickles & W. C. Horrace (Eds.), *Festschrift in honor of Peter Schmidt* (pp. 281–314). Springer. https://doi.org/10.1007/978-1-4899-8008-3_9

[34] Sohail, M. T., et al. (2021). Pakistan management of green transportation and environmental pollution: A nonlinear ARDL analysis. *Environmental Science and Pollution Research*. Springer. https://doi.org/10.1007/s11356-021-12654-x

[35] Tabrizi, A., Yousefi, H., Abdoos, M., & Ghasempour, R. (2025). Evaluating renewable energy adoption in G7 countries: A TOPSIS-based multi-criteria decision analysis. *Discover Energy, 5*(1), 2. https://doi.org/10.1007/s43937-025-00064-w

[36] Tang, C. F., & Tan, B. W. (2015). The impact of energy consumption, income and foreign direct investment on carbon emissions in Vietnam. *Energy, 79*, 447–454. https://doi.org/10.1016/j.energy.2014.11.033

[37] Tugcu, C. T., Ozturk, I., & Aslan, A. (2012). Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. *Energy Economics, 34*(6), 1942–1950. https://doi.org/10.1016/j.eneco.2012.08.02.

[38] Urom, C., Abid, I., Guesmi, K., & Ndubuisi, G. (2022). Renewable energy consumption, globalization, and economic growth shocks: Evidence from G7 countries. *The Journal of International Trade & Economic Development*, *31*(2), 204-232. https://doi.org/10.1080/09638199.2021.1961845

[39] Usman, M., Kousar, R., Yaseen, M. R., & Makhdum, M. S. A. (2020). An empirical nexus between economic growth, renewable energy consumption and environmental sustainability. *Environmental Science and Pollution Research, 27*, 30881–30893. https://doi.org/10.1007/s11356-020-09772-3

[40] Wooldridge, J. M. (2020). *Introductory econometrics: A modern approach* (7th ed.). Cengage Learning. https://doi.org/10.32614/cran.package.wooldridge

[41] Zhang, D., Mohsin, M., Rasheed, A. K., Chang, Y., & Taghizadeh-Hesary, F. (2021). Public spending and green economic growth: Evidence from renewable energy development. *Energy Economics*. https://doi.org/10.1016/j.enpol.2021.112256

[42] Zhang, M., Zhang, S., Lee, C. C., & Zhou, D. (2021). Effects of trade openness on renewable energy consumption in OECD countries: New insights from panel smooth transition regression modelling. *Energy Economics, 104*, 105649. https://doi.org/10.1016/j.eneco.2021.105649