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NONLINEAR EFFECTS OF PORTFOLIO INVESTMENT ON GREEN GROWTH IN PAKISTAN: A THRESHOLD REGRESSION ANALYSIS

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Abstract

*Green growth has become a central objective of sustainable development, requiring efficient financial mechanisms to support environmentally responsible economic transformation. Although foreign portfolio investment (FPI) represents an increasingly important source of external finance for developing economies, its contribution to green growth remains inconclusive due to its volatile nature and the potential for nonlinear effects. This study investigates whether the impact of portfolio investment on green growth in Pakistan varies across investment regimes by identifying a critical threshold level. The analysis employs annual time-series data for Pakistan covering the period **1995–2021** and applies **Hansen's (1999) Threshold Regression Model (TRM)** to examine the nonlinear relationship between portfolio investment and green growth. Renewable energy consumption, real GDP per capita, trade openness, and inflation are included as control variables. The findings identify an estimated portfolio investment threshold of **−0.103% of GDP;** however, the bootstrap threshold test indicates that the estimated threshold is statistically insignificant, suggesting no robust evidence of a nonlinear regime shift. Both the baseline and threshold models reveal that portfolio investment exerts a positive but statistically insignificant effect on green growth. The findings suggest that increasing portfolio investment alone is insufficient to promote green growth unless capital inflows are effectively channeled towards environmentally sustainable and productive sectors. Strengthening sustainable finance frameworks, capital market governance, and green investment policies is therefore essential for enhancing the environmental contribution of foreign capital. The study contributes to the sustainable finance literature by providing one of the first threshold-based empirical assessments of the portfolio investment–green growth nexus in Pakistan and offers valuable policy insights for advancing sustainable economic development.*

INTRODUCTION

The global pursuit of sustainable development has fundamentally transformed the relationship between economic growth, environmental sustainability, and financial markets. As countries strive to achieve the Sustainable Development Goals (SDGs) and fulfill their commitments under the Paris Climate Agreement, the concept of green growth has emerged as a strategic development paradigm that promotes economic prosperity while minimizing environmental degradation and resource depletion. Unlike conventional growth models that prioritize economic expansion regardless of ecological consequences, green growth seeks to improve environmental quality, encourage efficient resource utilization, stimulate technological innovation, and promote long-term economic resilience. Consequently, policymakers, international organizations, and financial institutions increasingly recognize that achieving sustainable development requires substantial financial resources directed toward environmentally responsible investments.

Financial markets play a central role in mobilizing capital for sustainable development by allocating resources toward productive investments and facilitating technological advancement. Traditionally, the literature has emphasized the importance of foreign direct investment (FDI), domestic investment, and financial development in promoting economic growth and environmental sustainability. However, with increasing globalization and financial liberalization, foreign portfolio investment (FPI) has become an important source of external finance for emerging economies. Portfolio investment provides liquidity to capital markets, enhances market efficiency, lowers financing costs, and strengthens investor confidence (Mustafa et al., 2024). Nevertheless, compared with FDI, portfolio investment is considerably more volatile because it responds rapidly to changes in macroeconomic conditions, monetary policy, political stability, and investor expectations (Ubaid-Ullah and Mustafa, 2025). These characteristics imply that portfolio investment may either promote sustainable development through improved capital allocation or hinder it by increasing financial instability and short-term speculative capital flows.

Recent developments in sustainable finance have further intensified interest in understanding how financial capital contributes to environmental sustainability. Green finance, sustainable investment funds, environmental, social and governance (ESG) investment strategies, and climate-related financial instruments have expanded rapidly during the past decade. Global investors increasingly consider environmental performance alongside financial returns, thereby encouraging firms and governments to adopt cleaner production technologies and environmentally sustainable investment practices. Although these developments suggest that financial markets can become powerful drivers of green growth, empirical evidence remains mixed regarding the role of portfolio investment in supporting environmental sustainability, particularly within developing economies where capital markets are relatively shallow and institutional quality remains heterogeneous.

Pakistan represents an important case for examining this relationship. As one of the most climate-vulnerable countries, Pakistan faces serious environmental challenges, including rising carbon emissions, increasing energy demand, rapid urbanization, water scarcity, and frequent climate-related disasters. At the same time, the country requires substantial financial resources to sustain economic growth, modernize infrastructure, accelerate renewable energy deployment, and achieve its climate commitments. The government has introduced several initiatives to improve financial sector development, strengthen capital markets, promote renewable energy, and encourage sustainable investment. Despite these reforms, Pakistan continues to experience considerable fluctuations in foreign portfolio investment due to domestic macroeconomic instability, exchange rate volatility, inflationary pressures, geopolitical uncertainty, and changing global financial conditions. These fluctuations raise an important policy question: Does portfolio investment

consistently promote green growth, or does its contribution depend on reaching a critical investment threshold?

The existing literature has extensively investigated the relationships among financial development, foreign direct investment, renewable energy, trade openness, and environmental sustainability. Similarly, numerous studies have examined the influence of green finance, technological innovation, and institutional quality on environmental performance and sustainable development. More recently, researchers have begun to recognize that financial and environmental relationships are inherently nonlinear rather than strictly linear. The effectiveness of financial development and green finance may change substantially after economies reach specific institutional, technological, or financial thresholds. Consequently, assuming a constant marginal effect of investment across all economic conditions may lead to misleading policy conclusions. Recent threshold-based studies demonstrate that the impact of financial development and green finance often strengthens only after surpassing critical levels of market maturity, governance quality, or financial depth.

Despite these advances, several important research gaps remain. First, the overwhelming majority of empirical studies concentrate on foreign direct investment, green finance, or financial development, whereas the specific contribution of foreign portfolio investment to green growth has received comparatively little attention. Second, empirical evidence for Pakistan remains limited, despite the country's increasing reliance on external capital inflows to finance sustainable development and climate-related investments. Third, most previous studies employ conventional linear econometric techniques that implicitly assume portfolio investment exerts the same influence regardless of its magnitude. Such an assumption is unlikely to hold because portfolio investment can generate positive environmental outcomes only after capital markets achieve sufficient scale, stability, and efficiency. At lower levels, volatile portfolio inflows may have limited or even adverse effects on sustainable development, whereas larger and more stable inflows may finance environmentally friendly technologies, renewable energy projects, and sustainable infrastructure. Consequently, identifying the critical threshold beyond which portfolio investment becomes environmentally productive represents an important unresolved issue in the sustainable finance literature.

From a methodological perspective, threshold regression models provide an appropriate framework for investigating these nonlinear dynamics. Unlike conventional linear regression, Hansen's Threshold Regression Model allows regression coefficients to change once an observed threshold variable exceeds an endogenously determined critical value. This methodology enables researchers to identify structural regime shifts and determine whether the influence of portfolio investment differs below and above the estimated threshold. The bootstrap inference procedure developed by Hansen further provides statistically robust estimates of threshold values without requiring arbitrary classification of investment regimes. Given the increasing evidence of nonlinear relationships in finance, environmental economics, and sustainable development, threshold regression offers a more realistic representation of the portfolio investment–green growth nexus than traditional linear specifications (Javed et al., 2024).

Against this background, the present study investigates the threshold effects of portfolio investment on green growth in Pakistan using annual data covering 1990–2024 and Hansen's Threshold Regression Model. The study develops a nonlinear empirical framework to determine whether portfolio investment contributes to green growth only after exceeding a critical threshold while controlling for other macroeconomic factors influencing environmental sustainability. By estimating endogenous threshold values, the analysis provides new evidence regarding the magnitude of portfolio investment required to generate meaningful environmental and economic benefits.

This study makes four important contributions to the existing literature. First, it extends the sustainable finance literature by examining the role of foreign portfolio investment, an external financing source that has received considerably less attention than foreign direct investment or financial development in green growth research. Second, it contributes methodologically by employing Hansen's Threshold Regression Model to identify nonlinear investment regimes and estimate critical threshold values rather than imposing a restrictive linear relationship. Third, it provides updated empirical evidence for Pakistan, an emerging economy facing simultaneous challenges of attracting international capital, maintaining macroeconomic stability, and achieving sustainable development objectives. Finally, the findings offer practical policy guidance regarding the level of portfolio investment required to maximize green growth, thereby supporting the design of effective capital market reforms, sustainable finance strategies, and climate-oriented investment policies.

2. Literature Review

The transition towards green growth has become a central objective of sustainable development policies, prompting researchers to investigate how financial resources can support environmentally sustainable economic transformation. Recent literature suggests that financial systems facilitate green growth by mobilizing capital for renewable energy, technological innovation, environmentally friendly infrastructure, and low-carbon production. However, the effectiveness of financial capital depends not only on its availability but also on its composition, allocation efficiency, institutional environment, and macroeconomic stability. Consequently, scholars have increasingly shifted their attention from conventional linear relationships to nonlinear frameworks that better explain the complex interaction between financial investment and environmental sustainability.

A growing body of literature demonstrates that financial development and green finance are fundamental drivers of green economic growth. Rashid et al. (2026) reported that financial development significantly enhances renewable energy–driven green economic growth in Pakistan, while exchange rate volatility generates asymmetric environmental effects, indicating that macroeconomic stability is essential for sustainable development. Similarly, Hussain et al. (2023) found that green finance and technological innovation substantially reduce environmental degradation by supporting cleaner production technologies and environmentally sustainable investments. Their findings suggest that an efficient financial system encourages the adoption of green technologies and improves environmental quality. Complementing these findings, Rukh et al. (2025) observed that green finance improves firms' environmental performance by increasing investment in environmentally responsible projects and promoting sustainable business practices. Likewise, Nabi et al. (2025) demonstrated that stringent environmental policies stimulate eco-innovation and strengthen green finance across different economic conditions, confirming that effective environmental governance enhances the contribution of financial markets to sustainable development (Raza et al., 2020). Collectively, these studies establish that financial development and green finance are indispensable components of green growth; however, they primarily evaluate broad financial indicators without distinguishing the role of specific forms of international capital such as portfolio investment.

Technological innovation and productive investment have also received considerable attention as mechanisms for improving environmental sustainability. Qin et al. (2026) revealed that research and development expenditure, capital investment, and government green subsidies significantly enhance green innovation efficiency among Pakistani manufacturing firms. The study further demonstrated that public financial support complements private investment by accelerating the adoption of environmentally friendly technologies and improving firms' competitiveness. Likewise, Suhrab et al. (2025) found that financial development and foreign

direct investment significantly improve sustainable energy productivity within China Pakistan Economic Corridor (CPEC) economies, whereas inflation weakens environmental performance by discouraging long-term investment in renewable energy projects. These findings imply that financial resources generate greater environmental benefits when accompanied by technological advancement, innovation, and stable macroeconomic conditions. Nevertheless, these studies primarily focus on foreign direct investment, corporate investment, or financial development, leaving the environmental implications of foreign portfolio investment largely unexplored.

Recent empirical evidence further indicates that the relationship between financial variables and environmental sustainability is inherently nonlinear. Rather than assuming constant marginal effects, several studies argue that the contribution of financial resources varies according to the level of economic development, institutional quality, and investment intensity. Ullah et al. (2021) employed the Panel Smooth Transition Regression (PSTR) model and demonstrated that renewable energy consumption reduces ecological footprints, whereas natural resource rents increase environmental degradation, with both effects differing significantly across threshold regimes. Similarly, Chi et al. (2025); Aslam et al., (2025) applied a panel threshold regression framework and found that green finance significantly reduces carbon emissions only after surpassing a critical investment threshold, while governance quality further strengthens its environmental effectiveness. These studies clearly indicate that threshold-based methodologies capture regime-dependent relationships more effectively than conventional linear models, thereby providing more reliable evidence for sustainable policy formulation.

Although the existing literature consistently supports the positive role of finance in promoting environmental sustainability, several inconsistencies remain. First, empirical findings differ regarding the magnitude and direction of financial variables because researchers employ different proxies, sample periods, and estimation techniques. Second, most studies examine aggregate financial development, green finance, renewable energy investment, technological innovation, or foreign direct investment, while foreign portfolio investment receives comparatively little attention despite its increasing importance in international capital markets. Third, the majority of Pakistan-focused studies rely on ARDL, NARDL, QARDL, DOLS, or conventional panel estimation methods that capture long-run or asymmetric relationships but are unable to identify structural regime shifts or critical investment thresholds. Consequently, the existing literature provides limited evidence regarding whether financial capital generates environmental benefits continuously or only after reaching a minimum level of investment.

Furthermore, the growing application of threshold econometric techniques demonstrates that sustainable development processes are characterized by nonlinear dynamics rather than constant linear responses. Studies employing threshold and transition models consistently report that financial resources produce stronger environmental outcomes once economies achieve sufficient financial depth, institutional capacity, or investment intensity. However, these threshold analyses have mainly focused on green finance, renewable energy, financial development, ecological footprints, and carbon emissions, while the threshold behavior of foreign portfolio investment remains largely unexplored. Considering the volatile nature of portfolio investment and its sensitivity to macroeconomic conditions, assuming a linear relationship may conceal important structural changes in its contribution to green growth.

Despite substantial progress in the green finance literature, empirical evidence on the nonlinear relationship between foreign portfolio investment and green growth remains extremely limited, particularly for Pakistan. Existing studies primarily investigate green finance, financial development, renewable energy, technological innovation, or foreign direct investment using linear or asymmetric econometric approaches that cannot identify critical investment

thresholds. To the best of current knowledge, no study has applied Hansen's Threshold Regression Model to determine the optimal portfolio investment level required to promote green growth in Pakistan. Therefore, this study fills an important theoretical, methodological, and empirical gap by examining the threshold effects of portfolio investment on green growth and providing evidence-based guidance for sustainable investment policies.

3. Research Methodology

3.1 Model Specification

This study investigates the nonlinear impact of foreign portfolio investment on green growth in Pakistan using Hansen's (1999) Threshold Regression Model (TRM). The threshold model is preferred because it allows the effect of portfolio investment to vary across different investment regimes by estimating an endogenous threshold value, thereby overcoming the restrictive assumption of linearity.

The functional relationship is specified as:

$GG_t = f(PI_t, RE_t, GDP_t, TO_t, INF_t)$

The corresponding linear econometric model is expressed as:

$$GG_t = \beta_0 + \beta_1 PI_t + \beta_2 RE_t + \beta_3 GDP_t + \beta_4 TO_t + \beta_5 INF_t + \varepsilon_t$$

Where the intercept, $\beta_1 - \beta_5$ is are the slope coefficients, and ε_t is the error term.

3.2 Variable Description

Variable	Symbol	Expected Sign
Green Growth	GG	Dependent
Portfolio Investment	PI	±
Renewable Energy Consumption	RE	+
Real GDP per Capita	GDP	+
Trade Openness	TO	±
Inflation	INF	−

3.3 Data and Sources

This study employs annual time-series data for Pakistan covering the period **1995–2025.** The selected period captures the post-financial liberalization era, characterized by increased portfolio investment, financial market development, and the implementation of sustainable development policies. Data for green growth, renewable energy consumption, real GDP per capita, trade openness, and inflation are obtained from the **World Development Indicators (World Bank),** while foreign portfolio investment data are collected from the **International Monetary Fund (IMF) Balance of Payments Statistics** and the **World Development Indicators (World Bank)**.

4. Empirical Results and Discussion

The empirical analysis is based on the balanced annual sample for Pakistan covering 1995–2021. Although the dataset was arranged for 1995–2025, the estimation period ends in 2021 because complete observations for the green-growth proxy and renewable-energy series were not available for the later years. No missing observations were interpolated.

4.1 Descriptive Statistics

Table 1. Descriptive Statistics

Variable	Observations	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque–Bera p-value
GG	27	5.164	5.273	8.821	1.149	2.051	−0.343	2.487	0.629
PI	27	0.104	0.035	0.712	−0.180	0.24	1.244	3.830	0.040

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RE	27	47.622	47.200	53.100	41.600	3.285	−0.107	2.129	0.600
GDP	27	1.732	1.721	5.202	−3.039	2.123	−0.166	2.687	0.835
TO	27	29.623	29.878	38.330	21.460	4.501	0.053	2.148	0.620
INF	27	8.105	7.692	20.286	2.529	4.159	0.838	4.190	0.176

Table 1 reports the distributional characteristics of the variables. Green growth records an average value of 5.164, with moderate variation across the sample period. Portfolio investment averages only 0.104% of GDP but ranges from −0.180% to 0.712%, confirming the volatile nature of portfolio capital flows in Pakistan. Renewable energy constitutes, on average, 47.622% of final energy consumption, while average GDP per capita growth is 1.732%. Trade openness averages 29.623% of GDP, whereas inflation averages 8.105%. The Jarque–Bera results indicate approximate normality for most variables; however, portfolio investment rejects normality at the 5% level, reflecting its pronounced volatility and occasional extreme movements.

4.2 Correlation Analysis

Table 2. Pearson Correlation Matrix

Variable	GG	PI	RE	GDP	TO	INF
GG	1.000	−0.156	−0.310	0.436	−0.707	−0.508
PI	−0.156	1.000	0.245	0.121	0.208	0.108
RE	−0.310	0.245	1.000	−0.143	0.421	0.382
GDP	0.436	0.121	−0.143	1.000	−0.274	−0.428
TO	−0.707	0.208	0.421	−0.274	1.000	0.666
INF	−0.508	0.108	0.382	−0.428	0.666	1.000

Green growth is positively correlated with GDP per capita growth but negatively associated with portfolio investment, renewable energy, trade openness, and inflation. The strongest relationship is observed between green growth and trade openness, with a coefficient of −0.707. Inflation is also negatively associated with green growth. Among the explanatory variables, the highest correlation is between trade openness and inflation at 0.666, which remains below the conventional 0.80 threshold. Therefore, the model does not appear to suffer from severe multicollinearity.

4.3 Unit-Root Tests

Table 3. ADF and KPSS Unit-Root Results

Variable	Form	ADF Statistic	ADF p-value	KPSS Statistic	KPSS p-value	Integration Decision
GG	Level	−4.230	0.001	0.220	0.100	I(0)
PI	Level	−3.174	0.022	0.287	0.100	I(0)
RE	Level	−0.921	0.781	0.729	0.011	Non-stationary
RE	First difference	−4.869	<0.001	0.119	0.100	I(1)
GDP	Level	−2.918	0.043	0.123	0.100	I(0)
TO	Level	−2.024	0.276	0.155	0.100	Mixed evidence
INF	Level	−3.961	0.002	0.076	0.100	I(0)

The ADF and KPSS tests indicate that green growth, portfolio investment, GDP per capita growth, and inflation are stationary at level. Renewable-energy consumption is non-stationary at level but becomes stationary after first differencing, indicating an I(1) process. Trade openness produces mixed evidence because the ADF test fails to reject the unit-root null, whereas the KPSS test does not reject stationarity. The mixed integration properties justify caution in interpreting the time-series results and support the use of additional robustness checks.

4.4 Baseline Linear Regression

Table 4. Baseline Linear Regression Results

Variable	Coefficient	Robust S.E.	t-statistic	p-value
Constant	16.917***	4.122	4.104	<0.001
PI	1.493	1.072	1.393	0.164
RE	−0.055	0.110	−0.499	0.618
GDP	0.189	0.139	1.359	0.174
TO	−0.329**	0.137	−2.409	0.016
INF	0.016	0.132	0.123	0.902
Model Statistics			Value	
R^2			0.579	
Adjusted R^2			0.478	
F-statistic			7.312	
Prob. (F-statistic)			<0.001	
Observations			27	

The baseline linear model explains that insignificant coefficient of portfolio investment suggests that its effect on green growth may be nonlinear, justifying the use of a threshold regression model. In contrast, the significant negative effect of trade openness indicates that Pakistan's trade structure remains relatively energy- and pollution-intensive, limiting its contribution to green growth.

4.5 Test for Threshold Effects

Table 5. Hansen-Type Threshold Test

Threshold variable	Estimated threshold	Approximate 95% confidence interval	F-statistic	Bootstrap p-value	Below-threshold observations	Above-threshold observations
PI (% of GDP)	−0.103	−0.108 to 0.260	4.332	0.228	7	20

The estimated threshold is −0.103% of GDP, implying a potential structural change in the portfolio investment–green growth relationship when portfolio equity flows move above this value. However, the bootstrap p-value of 0.228 exceeds the conventional significance levels. Therefore, the null hypothesis of no threshold effect cannot be rejected.

4.6 Threshold Regression Results

Table 6. Regime-Specific Threshold Regression

Variable	Coefficient	Robust S.E.	t-statistic	p-value
Constant	22.804***	5.632	4.049	<0.001
PI below threshold	12.179*	6.751	1.804	0.071
PI above threshold	0.196	1.052	0.186	0.853
RE	−0.163	0.127	−1.286	0.198
GDP	0.128	0.159	0.805	0.421

TO	−0.330**	0.141	−2.347	0.019
INF	0.007	0.115	0.065	0.948

Model Statistics	**Value**
R^2	0.637
Adjusted R^2	0.528
F-statistic	5.847
Prob. (F-statistic)	0.001
Observations	27

Portfolio investment below the estimated threshold has a positive coefficient of 12.179 and is weakly significant at the 10% level. Above the threshold, its coefficient declines to 0.196 and becomes statistically insignificant. Trade openness remains negative and significant, while renewable energy, GDP growth, and inflation remain insignificant. The threshold model explains approximately 63.7% of the variation in green growth, slightly more than the baseline linear specification.

4.7 Diagnostic Tests

Table 7. Diagnostic and Specification Tests

Test	Statistic	p-value	Decision
Breusch–Godfrey LM	1.787	0.181	No serial correlation
Breusch–Pagan	8.538	0.201	No heteroskedasticity
Jarque–Bera	1.972	0.373	Residuals are normally distributed
Ramsey RESET	1.745	0.202	Model is correctly specified
Durbin–Watson	1.625	–	No serious residual autocorrelation

The Breusch–Godfrey test fails to detect serial correlation, while the Breusch Pagan result indicates homoscedastic residuals. The Jarque Bera probability confirms residual normality, and the Ramsey RESET test provides no evidence of functional-form misspecification. The Durbin–Watson statistic is reasonably close to 2. Overall, the diagnostic results support the statistical adequacy of the estimated model.

5. Conclusion and Policy Implications

This study examined the nonlinear effects of foreign portfolio investment on green growth in Pakistan using annual data for the period 1995–2021 and Hansen's Threshold Regression Model. Unlike previous studies that primarily focused on green finance, financial development, or foreign direct investment, this study investigated whether the contribution of portfolio investment to green growth changes after crossing a critical investment threshold. The empirical findings revealed that although a potential threshold value exists, the bootstrap threshold test does not provide sufficient statistical evidence to confirm a significant nonlinear regime shift. Therefore, the hypothesis that portfolio investment exerts different effects on green growth across investment regimes is not strongly supported by the available data.

The baseline and threshold regression results indicate that portfolio investment has a positive but statistically insignificant association with green growth. This suggests that conventional portfolio capital inflows alone are insufficient to promote environmentally sustainable economic growth unless they are effectively channeled toward green and productive sectors. Among the control variables, trade openness exhibits a significant negative relationship with green growth, implying that Pakistan's current trade structure may still be dominated by resource-intensive and environmentally unsustainable economic activities. In contrast, renewable energy consumption, economic growth, and inflation do not show statistically significant effects within the estimated model.

These findings provide several important policy implications. First, policymakers should focus on

improving the quality rather than merely the volume of portfolio investment by encouraging investment in renewable energy, green infrastructure, clean technologies, and environmentally responsible industries. Second, financial regulators should strengthen sustainable finance frameworks by introducing green investment guidelines, environmental disclosure standards, and sustainability-linked financial instruments to attract environmentally responsible international investors. Third, trade policies should be aligned with environmental objectives by promoting exports from cleaner industries while encouraging the adoption of low-carbon technologies in export-oriented sectors. Finally, strengthening capital market governance, institutional quality, and macroeconomic stability will enhance investor confidence and improve the efficient allocation of portfolio capital toward sustainable economic activities.

Despite its contribution, this study has several limitations. The analysis is based on annual time-series data for a single country, which restricts the sample size and may reduce the statistical power of threshold estimation. In addition, the study considers only a single threshold and does not account for possible multiple-regime dynamics or structural breaks. Future research may extend this analysis by employing quarterly or panel data, estimating multiple-threshold models, incorporating alternative green growth indicators, and examining the moderating role of institutional quality, green finance, or environmental governance in the portfolio investment–green growth relationship.

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