

## An Empirical Analysis of Financial Development, Energy Consumption, and Ecological Footprint in Pakistan

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### ABSTRACT

Environmental degradation poses serious challenges to sustainable development in Pakistan, where economic expansion, financial sector growth, and rising energy demand place increasing pressure on natural resources. This study examines the relationships among financial development, renewable and non-renewable energy consumption, trade openness, ecological footprint, and economic growth using annual data for the period 1990–2019. The Autoregressive Distributed Lag (ARDL) approach is employed to explore both short-run and long-run dynamics among the variables. The empirical findings reveal that non-renewable energy consumption and economic growth significantly increase the ecological footprint, indicating greater environmental pressure. In contrast, renewable energy consumption and trade openness contribute to environmental improvement by reducing ecological degradation. Financial development shows a favorable environmental effect in the short run; however, its long-run impact on environmental quality is statistically weak. The results further indicate that financial development, renewable energy use, non-renewable energy use, and trade openness positively contribute to economic growth. Overall, the findings suggest that economic growth alone is insufficient to ensure environmental sustainability. A structural transformation of the energy system is necessary, with greater reliance on renewable energy sources. The study recommends promoting green financing, strengthening environmental regulations, and encouraging the adoption of energy-efficient technologies to achieve long-term sustainable development in Pakistan.

### 1. Introduction

Environmental sustainability has emerged as a major challenge for policymakers and researchers worldwide, particularly in developing economies such as Pakistan. Over the past three decades, rapid industrialization, population growth, urban expansion, and rising income levels have substantially increased pressure on natural resources and ecosystems (Ulucak & Bilgili, 2018; Yilanci et al., 2019). Although economic growth improves living standards and reduces poverty, it simultaneously increases energy demand and resource utilization. The persistent reliance on fossil fuels has led to higher greenhouse gas emissions, widely recognized as a primary driver of climate change and environmental degradation (Dogan et al., 2019). Consequently, developing countries face the challenge of sustaining economic growth while maintaining ecological balance.

Environmental degradation has traditionally been assessed using carbon dioxide (CO<sub>2</sub>) emissions. However, CO<sub>2</sub> emissions capture only a single dimension of biospheric pressure and fail to represent the overall ecological impact of

human activities. Recently, the ecological footprint has been proposed as a more comprehensive indicator of sustainability (Solarin & Bello, 2018). Unlike single-pollutant measures, this indicator captures the demand placed on biologically productive land and water resources relative to the Earth's regenerative capacity. By incorporating cropland, forests, fisheries, and grazing land, it provides a broader assessment of ecological stress.

The relationship between economic growth and ecological pressure is commonly explained by the Environmental Kuznets Curve (EKC) hypothesis (Grossman & Krueger, 1991; Grossman & Krueger, 1995). According to the EKC, such pressure initially rises with income growth but declines after a certain threshold, as economies adopt cleaner technologies and implement stricter regulations (Dinda, 2004; Stern, 2004). Nevertheless, empirical evidence supporting the EKC remains inconclusive, particularly in developing countries where institutional capacity and governance are relatively weak (Ozturk & Acaravci, 2013; Al-Mulali et al., 2015). This suggests that economic growth alone may not automatically lead to ecological improvement.

Financial development is another key factor influencing the quality of natural systems. A well-developed financial system enhances capital allocation efficiency, stimulates investment, and promotes technological innovation (Tamazian & Rao, 2010; Abbasi & Riaz, 2016). Greater access to credit enables firms to adopt energy-efficient technologies and cleaner production methods, while financial institutions can finance renewable energy projects and other sustainable activities. Consequently, the expansion of the financial sector may improve environmental quality in the long run.

However, the impact of the financial sector on natural systems is ambiguous. Greater access to finance can stimulate industrial production, consumption, and infrastructure expansion, increasing energy demand and emissions (Sadorsky, 2010; Acheampong, 2019). Accordingly, it may mitigate resource degradation through technological advancement (technique effect) or intensify pressure on ecosystems via higher economic activity (scale effect). The overall outcome depends on how financial resources are allocated and the effectiveness of sustainability policies.

Energy consumption plays a central role in this relationship because modern economic activities rely heavily on energy inputs for industrial production, transportation, and agriculture (Stern & Cleveland, 2004). The environmental impact varies according to the energy source. Non-renewable energy sources, including coal, oil, and natural gas, are major contributors to greenhouse gas emissions (Apergis et al., 2010). In contrast, renewable energy sources such as solar, wind, and hydropower generate significantly lower emissions and offer a viable pathway toward sustainable development presented in figure 1.

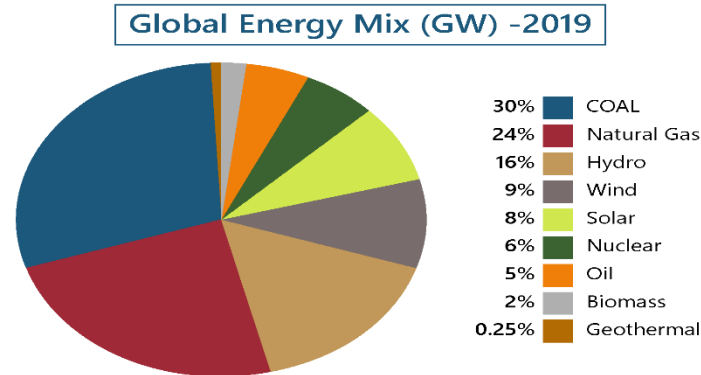
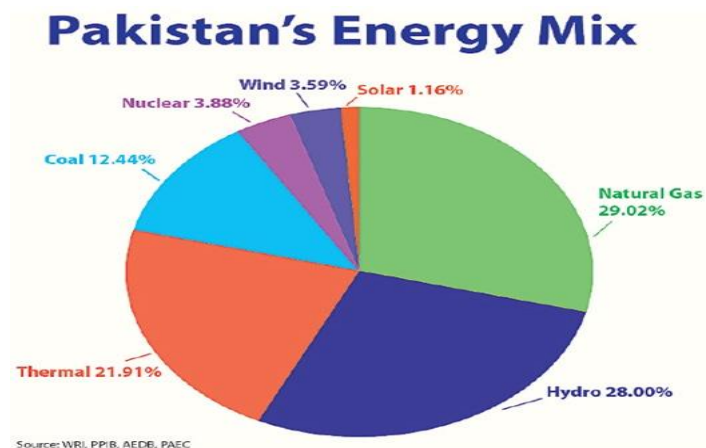


Figure 1: Global Energy Mix

Developing economies often experience rising energy demand due to industrial expansion, transportation development, and agricultural modernization. Higher income levels increase consumption of energy-intensive goods and services, leading to greater resource extraction and waste generation. At the same time, limited technological capacity, financial constraints, and weak enforcement of environmental regulations hinder the transition toward sustainable energy systems (Destek & Sarkodie, 2019; Aşıcı & Acar, 2016; Danish & Wang, 2019; Sarkodie & Strezov, 2019).

Pakistan provides an appropriate case for examining these dynamics. The country's economic growth depends heavily on energy-intensive sectors such as agriculture, manufacturing, and services. Rapid population growth and urbanization have significantly increased energy demand. Although Pakistan possesses considerable renewable energy potential, fossil fuels continue to dominate the energy mix due to infrastructure limitations, financial barriers, and policy implementation challenges (Baloch et al., 2016; Sheikh, 2010). Consequently, environmental degradation has intensified alongside economic expansion in figure 2.

Figure 2: Pakistan's Energy Mix



While previous studies on Pakistan have mainly focused on the relationship between energy consumption and carbon emissions, fewer studies have adopted a broader environmental indicator such as the carbon footprint. Moreover, limited research has jointly examined economic diversification, renewable and non-renewable energy consumption, trade openness, and economic growth within a unified empirical framework. This gap is particularly important for Pakistan, where financial sector expansion and energy policy reforms are ongoing.

Against this backdrop, the present study investigates the dynamic relationships among inclusive growth, renewable energy consumption, non-renewable energy consumption,

trade openness, environmental impact assessment, and economic growth in Pakistan using annual data from 1990 to 2019. The Autoregressive Distributed Lag (ARDL) model is employed to estimate both short-run and long-run relationships among the variables. By using ecological footprint as a comprehensive measure of environmental degradation and distinguishing between renewable and non-renewable energy sources, this study provides a more complete understanding of the finance-energy environment nexus in Pakistan. The findings aim to offer practical policy insights for promoting sustainable economic growth through green financing, renewable energy investment, and effective environmental regulation.

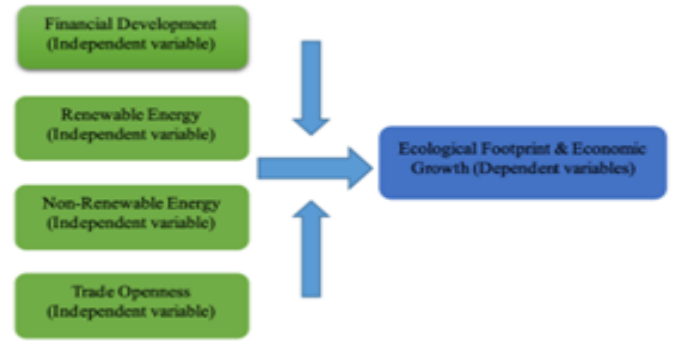
**2. Materials and Methods**

This study utilizes annual time-series data for Pakistan spanning the period from 1990 to 2019. The data are collected from reputable international sources, including the World Development Indicators, the Global Footprint Network, and the International Monetary Fund databases, ensuring reliability and consistency. The key variables incorporated in the analysis are Ecological Footprint (EFP), which serves as a comprehensive measure of environmental degradation; Financial Development (FD), representing the depth and efficiency of the financial sector; Renewable Energy Consumption (REC) and Non-Renewable Energy Consumption (NREC), which capture the differential impacts of clean and conventional energy use; Trade Openness (TOP), reflecting the extent of Pakistan’s integration into the global economy; and Economic Growth (GDP), indicating the level of economic activity.

To examine the dynamic relationships among these variables, the study employs the Autoregressive Distributed Lag (ARDL) model. The ARDL approach is particularly appropriate in situations where variables are integrated at different orders, that is, a mixture of I(0) and I(1), and when the sample size is relatively small. Moreover, the model enables the estimation of both short-run and long-run relationships within a unified framework, making it well-suited for time-series analysis in the context of Pakistan’s economic and environmental dynamics.

**Conceptual Framework**

The conceptual framework explains the expected relationships among financial development, energy consumption, ecological footprint, and economic growth. It identifies the key variables and hypothesizes their interactions.



**Figure 3: Conceptual Framework**

Table 1 presents the definitions, measurements, and data sources of the variables used in the study. The ecological footprint (EFP) is used as a proxy for environmental degradation and is measured in per capita international hectares. The data for EFP are obtained from the Global Footprint Network (GFPN). Economic growth (GDP) is measured as the annual percentage growth rate of gross domestic product, with data sourced from the World Development Indicators (WDI).

**Table 1: Variables Description**

Variables	Description	Sources
<b>EFP</b>	Environmental footprint is measured per capita international hectares.	GFPN
<b>GDP</b>	GDP represents annual percentage growth of gross domestic product	WDI
<b>FD</b>	Financial development received as % of GDP	IMF
<b>REC</b>	REC is expressed as a proportion of overall final energy consumption	WDI
<b>NREC</b>	Non-renewable energy is expressed in kilograms of oil equivalent per capita.	WDI
<b>TOP</b>	Trade openness is measured as the sum of exports and imports as a percentage of GDP. The all parameters	WDI

Financial development (FD) is expressed as a percentage of GDP and reflects the depth and performance of the financial sector; the data are collected from the International Monetary Fund (IMF). Renewable energy consumption (REC) is measured as a proportion of total final energy consumption, while non-renewable energy consumption (NREC) is expressed in kilograms of oil equivalent per capita. Both

REC and NREC data are sourced from the World Development Indicators. Trade openness (TOP) is calculated as the sum of exports and imports as a percentage of GDP, and its data are also obtained from the World Development Indicators. Together, these variables provide a comprehensive framework for analyzing the relationship between economic activity, energy consumption, financial development, and environmental sustainability.

### Theoretical Background

Financial development influences environmental sustainability through multiple channels. A well-functioning financial system improves capital allocation, promotes technological innovation, and supports investment in energy-efficient production processes. Access to finance enables firms to adopt cleaner technologies and reduce environmental damage. However, financial development may also increase pollution if financial resources are directed toward energy-intensive industries (Tamazian et al., 2009; Sadorsky, 2010).

Energy consumption is a major determinant of economic growth and environmental sustainability. Modern economies depend heavily on energy for industrial production, transportation, and agricultural activities. Non-renewable energy sources such as coal, oil, and natural gas contribute significantly to environmental degradation. In contrast, renewable energy sources including solar, wind, and hydropower help reduce ecological pressure and promote sustainable development (Apergis et al., 2010; Dogan et al., 2019).

Trade openness also affects environmental quality through several mechanisms. According to the scale, technique, and composition effects of trade, increased trade may initially increase environmental pressure due to higher production levels. However, trade can also facilitate the transfer of advanced technologies and promote cleaner production methods (Grossman & Krueger, 1995; Copeland & Taylor, 2004).

Furthermore, the Environmental Kuznets Curve hypothesis suggests that environmental degradation increases during the early stages of economic growth but declines after a certain level of income was achieved. This implies that developing economies may experience higher environmental pressure before transitioning toward sustainable development (Ulucak & Bilgili, 2018).

### Hypotheses Development

Based on the theoretical framework and previous literature, the following hypotheses were developed:

H1: Financial development significantly affects ecological footprint.

H2: Renewable energy consumption reduces ecological footprint.

H3: Non-renewable energy consumption increases ecological footprint.

H4: Trade openness improves environmental quality.

H5: Economic growth increases ecological footprint.

### Model Specification

To address the study objectives, two econometric models are developed, with Model 1 focusing on the Ecological Footprint as the dependent variable. The general form of Model 2 is also specified to capture the extended relationship among the selected macroeconomic and energy-related variables. These two model specifications allow for a comprehensive examination of both the direct and dynamic effects of financial development, energy consumption patterns, trade openness, and economic growth on environmental sustainability. By structuring the analysis into two interconnected models, the study ensures robustness in estimation and provides clearer insights into both short-run and long-run relationships. This dual-model framework strengthens the empirical investigation and enhances the reliability of the results.

#### Model 1: Ecological Footprint:

##### General form of model 1

$$EFP = f(FD, REC, NREC, TOP, GDP) \quad (1)$$

The equation in linear form becomes:

$$EFP = \alpha_0 + \alpha_1 FD + \alpha_2 REC + \alpha_3 NREC + \alpha_4 TOP + \alpha_5 GDP + \mu$$

The variables in Eq. 1 are the major indicators that influence the quality of environment (Khalid et al., 2021). To avoid the effects of heteroscedasticity and data sharpness, we converted all variables into logarithmic form.

$$\text{LogEFP} = \alpha_0 + \alpha_1 \text{logFD} + \alpha_2 \text{logREC} + \alpha_3 \text{logNREC} + \alpha_4 \text{logTOP} + \alpha_5 \text{logGDP} + \mu \quad (2)$$

The logarithmic representation of all under-examined parameters is represented by the symbol log in Eq. 2.  $\mu$  represents the stochastic error term. All parameters  $\alpha_1$ ,  $\alpha_2$ ,  $\alpha_3$ ,  $\alpha_4$ , and  $\alpha_5$  are representing the elasticity of all factors.

##### General form of model 2

$$GDP = f(FD, REC, NREC, TOP) \quad (3)$$

The equation in linear form becomes:

$$GDP = \beta_0 + \beta_1 FD + \beta_2 REC + \beta_3 NREC + \beta_4 TOP$$

The parameters in Eq.3 are the major indicators that boost the economic expansion.

In case of Eq. 3, the logarithmic form represented as follows:

$$\text{LogGDP} = \beta_0 + \beta_1 \text{logFD} + \beta_2 \text{logREC} + \beta_3 \text{logNREC} + \beta_4 \text{logTOP} + \mu \quad (4)$$

In Eq. 4, the intercept is represented by  $\beta_0$  while the residual is represented by  $\mu$ . And  $\beta_1$ ,  $\beta_2$ ,  $\beta_3$ , as well as  $\beta_4$  represent the elasticity of all variables.

### Methodological Framework

The ARDL approach is used to examine both short-run and long-run relationships among variables. Prior to estimation,

stationarity of the data is checked using the Augmented Dickey-Fuller (ADF) test to avoid spurious regression results.

**Unit Root Test (ADF)**

- **H<sub>0</sub>:** Variable is non-stationary
- **H<sub>1</sub>:** Variable is stationary

A variable is considered stationary if the ADF test statistic exceeds the critical value or the p-value is less than 0.05.

**Autoregressive Distributed Lag (ARDL) Model**

- Used to estimate long-run relationships and short-run dynamics simultaneously.
- Suitable for small sample sizes (30–80 observations).
- Avoids endogeneity problems and allows construction of an Error Correction Model (ECM).

**Cointegration Test**

- The **Bounds testing approach** determines long-run associations among FD, REC, NREC, TOP, EFP, and GDP.

- **H<sub>0</sub>:** No cointegration
- **H<sub>1</sub>:** Cointegration exists
- The null is rejected if the calculated F-statistic exceeds the upper critical bound.

**Error Correction Mechanism (ECM)**

- Measures short-term dynamics and speed of adjustment to long-run equilibrium.
- Coefficient should be negative and significant (between 0 and -1) to confirm meaningful long-term relationships.

**3. Results and Discussion**

This section presents the empirical findings obtained using the Autoregressive Distributed Lag (ARDL) approach. Prior to model estimation, the stationarity properties of the variables were examined using the Augmented Dickey–Fuller (ADF) unit root test to determine the appropriate order of integration.

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

Variables	ADF at Level (t-stat)	P-value	ADF at First Difference (t-stat)	P-value	Order of Integration
EFP	-1.259944	0.1862	-6.292952	0.0000	I(1)
FD	-0.701538	0.4041	-4.422566	0.0001	I(1)
REC	-1.263094	0.1849	-5.687448	0.0000	I(1)
NREC	-2.404085	0.1494	-6.031133	0.0000	I(1)
GDP	-3.754588	0.0083	-6.260675	0.0000	I(0)
TOP	-0.367802	0.5432	-5.457347	0.0000	I(1)

**Unit Root Analysis**

Prior to estimating the Autoregressive Distributed Lag (ARDL) model, the stationarity properties of the variables were examined using the Augmented Dickey–Fuller (ADF) unit root test. The results are reported in Table 2. The findings show that ecological footprint (EFP), financial development (FD), renewable energy consumption (REC), non-renewable energy consumption (NREC), and trade openness (TOP) are non-stationary at level but become stationary after first differencing, indicating integration of order one, I(1). In contrast, economic growth (GDP) is stationary at level, implying integration of order zero, I(0). Since the variables are integrated at mixed orders, I(0) and I(1), and none is integrated at order two, the ARDL approach is appropriate for examining both short-run and long-run relationships.

**ARDL Bounds Test for Cointegration**

Table 3 examines the existence of a long-run equilibrium relationship among the variables, the ARDL bounds testing procedure was employed. The computed F-statistic is 11.05165, which exceeds the upper critical bound at the 1%, 2.5%, 5%, and 10% significance levels. This result confirms

the presence of cointegration among ecological footprint, financial development, renewable and non-renewable energy consumption, trade openness, and economic growth. Therefore, both long-run coefficients and short-run dynamics can be estimated within the ARDL framework.

**Table 3: ARDL Bounds Test Results**

Test Statistic	Value	K
F-statistic	11.05165	5
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

The computed F-statistic (11.05165) exceeds the upper critical bounds at all significance levels, confirming the presence of cointegration among the variables. Hence, both

short-run and long-run estimates can be derived within the ARDL framework.

**Short-Run Results**

Table 4 reports the short-run error correction model (ECM) estimates where ecological footprint is the dependent variable.

**Table 4: Short-Run ECM Estimates (Dependent Variable: EFP)**

Variables	Coefficient	Probability
D(FD)	-0.046927	0.0431
D(REC)	-0.389211	0.0544
D(NREC)	0.765994	0.0134
D(GDP)	0.037997	0.0156
D(TOP)	-0.228202	0.0070
CointEq(-1)	0.972509	0.0006

Table 4 presents the financial development has a negative and statistically significant coefficient (-0.0469,  $p < 0.05$ ), indicating that short-run improvements in the financial sector are associated with a reduction in environmental pressure. Renewable energy consumption also exhibits a negative coefficient (-0.3892), suggesting that increased use of renewable energy lowers the ecological footprint in the short run.

In contrast, non-renewable energy consumption has a positive and significant effect (0.7660,  $p < 0.05$ ), implying that fossil fuel use increases environmental degradation. Economic growth shows a positive and significant coefficient (0.0380), indicating that expansion in economic activity raises ecological pressure. Trade openness has a negative and significant coefficient (-0.2282), suggesting that greater integration into international markets is associated with improved environmental quality. The error correction term, CointEq(-1), is negative and statistically significant (-0.9725,  $p < 0.01$ ). This confirms the existence of a stable long-run equilibrium relationship and indicates a rapid adjustment toward equilibrium, with approximately 97% of short-run deviations corrected within one year.

**Long-Run Results**

**Table 5: Long-Run ARDL Estimates**

Variables	Coefficient	Probability
FD	-0.105556	0.6299
REC	-0.284975	0.0431
NREC	0.620312	0.0298
GDP	0.095348	0.0079
TOP	-0.188006	0.0415
C	-2.487041	0.0264

The long-run ARDL estimates are presented in Table 5. Financial development shows a negative but statistically

insignificant effect on ecological footprint (-0.1056), indicating that its long-term environmental influence is weak. Renewable energy consumption significantly reduces the ecological footprint (-0.2850,  $p < 0.05$ ), while non-renewable energy consumption significantly increases it (0.6203,  $p < 0.05$ ).

Economic growth has a positive and significant effect (0.0953,  $p < 0.01$ ), suggesting that long-term economic expansion contributes to environmental pressure. Trade openness exhibits a negative and significant coefficient (-0.1880,  $p < 0.05$ ), indicating that openness to trade is associated with environmental improvement.

Diagnostic statistics support model adequacy. The coefficient of determination ( $R^2 = 0.9379$ ) indicates strong explanatory power, and the Durbin-Watson statistic (2.056) suggests absence of autocorrelation.

**GDP Model: ARDL Results**

Short-run ARDL estimates for economic growth are presented in Table 6. Financial development (2.5364), renewable energy consumption (9.6595), non-renewable energy consumption (3.8871), and trade openness (2.2255) all have positive and statistically significant effects on GDP.

**Table 6: Short-Run ARDL Estimates (Dependent Variable: GDP)**

Variable	Coefficient	Probability
D(FD)	2.536356	0.0370
D(REC)	9.659468	0.0287
D(NREC)	3.887060	0.0039
D(TOP)	2.225531	0.0421
CointEq(-1)	-0.761329	0.0112

The error correction term (-0.7613,  $p < 0.05$ ) is negative and significant, confirming convergence toward long-run equilibrium. Approximately 76% of short-run disequilibrium is corrected each year.

**Long-Run Results**

Table 7 shows the long-run results indicate that financial development, energy consumption, and trade openness positively influence economic growth. Renewable energy consumption (12.7484,  $p < 0.05$ ) and non-renewable energy consumption (9.5153,  $p < 0.05$ ) significantly increase GDP, while trade openness also contributes positively (2.5918,  $p < 0.05$ ). Financial development has a positive but statistically insignificant long-run effect.

**Table 7: Long-Run ARDL Estimates (Dependent Variable: GDP)**

Variables	Coefficient	Probability
FD	0.234518	0.3315
REC	12.748402	0.0265
NREC	9.515295	0.0118
TOP	2.591832	0.0152
C	86.146008	0.0122

Model diagnostics confirm adequacy, with  $R^2 = 0.9665$  and Durbin–Watson = 2.033, indicating strong explanatory power and no serial correlation.

**Model Stability and Diagnostic Tests**

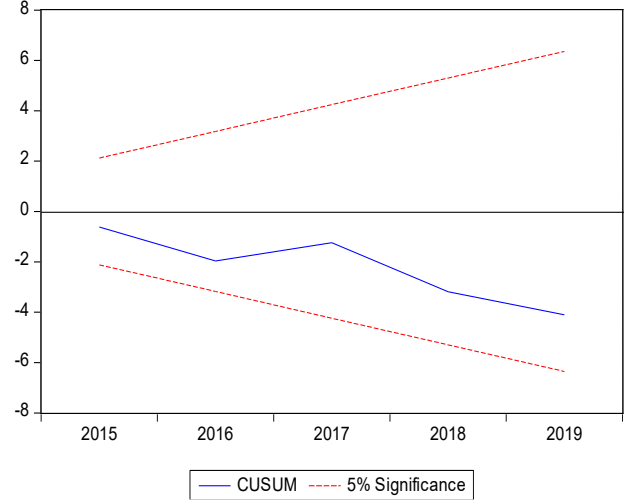
Stability tests using CUSUM and CUSUMSQ confirm that parameters remain within 5% critical bounds, indicating model stability. Diagnostic tests further confirm reliability. Table 8 reports the several diagnostic tests were conducted to ensure model reliability. The Breusch–Godfrey LM test indicates absence of serial correlation, while the Breusch–Pagan test confirms homoscedastic residuals. The Jarque–Bera statistic supports the normality of residuals. The overall F-statistics for both models are statistically significant, confirming joint significance of the regressors.

Model stability was further evaluated using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests. Both statistics lie within the 5% critical bounds, indicating parameter stability over the sample period. Therefore, the estimated ARDL models are stable in both the short run and the long run. **Table 8: Diagnostic Test Summary**

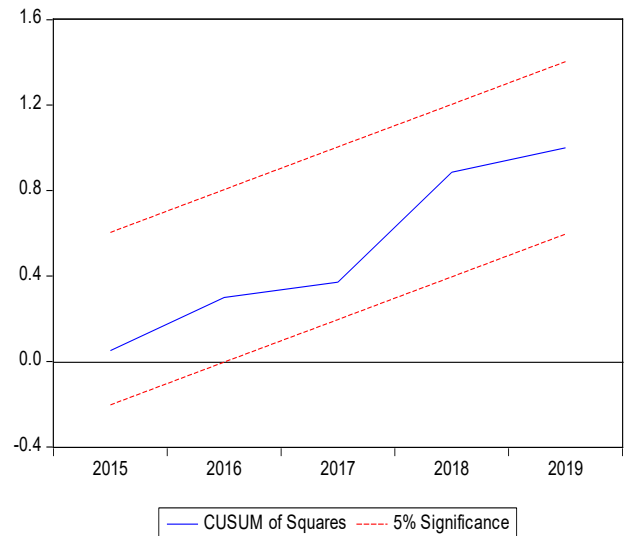
Test	Statistic	P-value	Conclusion
$R^2$ (EFP)	0.9379	–	Good fit
F-stat (EFP)	7.9965	0.0016	Significant
DW (EFP)	2.056	–	No autocorrelation
LM Test	–	0.7076	No serial correlation
Breusch-Pagan	–	0.7538	Homoscedastic
Jarque-Bera	–	0.4813	Normal distribution
$R^2$ (GDP)	0.9665	–	Good fit
F-stat (GDP)	7.2217	0.0187	Significant
DW (GDP)	2.033	–	No autocorrelation

Model stability was assessed using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests as proposed by Pesaran and Shin (1999). The null hypothesis states that all coefficients are stable. At the 5% significance level, both CUSUM and CUSUMSQ statistics remain within the critical bounds, indicating parameter stability. Therefore,

the null hypothesis is accepted, confirming the stability of both long- and short-run estimates reports in figure 4 and 5.



**Figure 4: Cumulative sum of recursive residuals (CUSUM)**



**Figure 5: Cumulative sum of squares of recursive residuals (CUSUMSQ)**

**Discussion**

The empirical findings provide important insights into the interaction between economic activity and sustainability in Pakistan. Non-renewable energy consumption significantly increases the ecological footprint, confirming that reliance on fossil fuels remains a primary source of resource pressure. Pakistan’s energy system is still dominated by conventional fuels, and combustion of oil, gas, and coal

generates substantial greenhouse gas emissions while depleting natural resources. These results align with previous studies indicating that developing economies dependent on fossil fuels experience heightened ecological stress (Dogan et al., 2019; Sarkodie & Strezov, 2019). This outcome reflects the scale effect of energy use, where rising production and energy demand exacerbate environmental degradation.

In contrast, renewable energy consumption reduces the ecological footprint, highlighting the benefits of cleaner energy sources. Renewable technologies require less fossil fuel input and generate substantially lower emissions than traditional energy systems. Expansion of renewable capacity therefore contributes to improved ecological outcomes in Pakistan while also supporting output growth. This finding supports the sustainable development perspective, which emphasizes that cleaner energy technologies can foster economic advancement while minimizing resource depletion.

Credit market development exerts a dual influence on sustainability. In the short run, greater access to finance facilitates investment in modern and energy-efficient technologies, reducing resource pressure. Over time, however, expanded credit availability may stimulate consumption, infrastructure expansion, and industrial activity, which increase energy demand and partially offset these benefits. This dual role highlights the complex finance–environment nexus, where sector growth can either improve or intensify ecological stress depending on how resources are allocated and regulated. Similar mixed findings have been reported by Tamazian and Rao (2010) and Acheampong (2019), emphasizing that effective regulatory frameworks and energy sector structure shape the ultimate environmental impact.

Trade openness also produces mixed outcomes. Integration into international markets provides access to cleaner technologies, efficient capital equipment, and advanced production methods, enabling firms to increase output with fewer ecological costs. This result reflects the “technique effect” of trade theory, where global integration facilitates adoption of environmentally friendly practices. At the same time, trade expansion stimulates economic activity, which can increase resource use if environmental safeguards are insufficient.

Economic expansion itself raises the ecological footprint in Pakistan. Industrial growth, transportation, and urban infrastructure development elevate energy consumption and resource extraction, consistent with the early phase of the Environmental Kuznets Curve (EKC), where ecological pressure increases with income before technological progress and stronger regulation begin to reduce impact. Pakistan appears to remain in this resource-intensive stage of development.

Both renewable and non-renewable energy support output growth, underscoring the central role of energy in production and development. However, renewable energy provides a more

capital allocation, encouraging investment, and enhancing productivity.

Overall, the findings indicate that Pakistan’s current development pattern is heavily energy-intensive and exerts significant pressure on natural resources. While fossil fuels continue to drive economic expansion, they generate substantial ecological costs. Renewable energy offers a viable pathway toward sustainable development, but its effectiveness depends on complementary financial reforms and supportive trade and policy frameworks. Integrating energy policy with credit sector development and trade strategy is therefore essential to reduce resource degradation while maintaining economic growth.

#### 4. Conclusion

This study examined the dynamic relationships among financial development, renewable and non-renewable energy consumption, trade openness, ecological footprint, and economic growth in Pakistan over the period 1990–2019 using the Autoregressive Distributed Lag (ARDL) approach. By employing ecological footprint as a comprehensive proxy for environmental degradation and distinguishing between renewable and non-renewable energy sources, the study provides an integrated assessment of the finance–energy–environment nexus within the context of a developing economy.

The empirical findings indicate that Pakistan’s economic growth remains highly energy-intensive and environmentally costly. Non-renewable energy consumption significantly increases the ecological footprint, confirming that fossil-fuel dependence remains a principal driver of environmental degradation. Conversely, renewable energy consumption contributes to a reduction in ecological pressure while simultaneously promoting economic growth. These findings suggest that a transition toward cleaner energy sources can support economic expansion without exacerbating environmental damage.

Financial development exerts a positive influence on economic growth and demonstrates a short-run environmental benefit. However, its long-run effect on environmental quality is statistically insignificant, implying that the environmental gains associated with financial sector expansion may weaken over time. This outcome reflects the dual role of financial development: while improved access to credit can facilitate investment in energy-efficient technologies, it may also stimulate consumption and production activities that increase energy demand. Trade openness is found to enhance economic performance while reducing environmental degradation, likely through

technology transfer, efficiency gains, and improved production techniques.

Collectively, these results indicate that Pakistan is currently positioned in the resource-intensive phase of development, where economic expansion increases environmental pressure. Without structural reforms in the energy and financial sectors, continued growth may further intensify ecological degradation.

### **Policy and Practical Implications**

The empirical evidence offers several policy implications directly aligned with the study's findings.

First, accelerating the transition toward renewable energy is essential. Given the adverse environmental impact of non-renewable energy and the dual economic–environmental benefits of renewable sources, policymakers should prioritize investment in solar, wind, and other clean energy infrastructure. Strengthening grid integration, improving regulatory certainty, and encouraging private-sector participation will be critical to scaling renewable energy deployment.

Second, the financial sector should be strategically aligned with environmental objectives. The short-run environmental benefits of financial development highlight the importance of targeted credit allocation. Policymakers and financial regulators should promote green financing instruments, including green bonds, concessional loans for renewable projects, and sustainability-linked credit facilities. Incorporating environmental risk assessment into financial decision-making frameworks would further enhance the role of finance in supporting sustainable development.

Third, environmental regulatory frameworks must be strengthened to ensure that economic expansion does not translate into increased ecological pressure. Implementing stricter emission standards, incentivizing energy-efficient technologies, and improving monitoring and enforcement mechanisms can mitigate the environmental consequences of industrial growth.

Fourth, trade policy should facilitate access to environmentally friendly technologies and capital goods. Reducing barriers to the import of clean technologies and energy-efficient machinery can enhance domestic production efficiency and lower environmental intensity.

Fifth, fiscal reforms are necessary to correct market distortions that favor fossil fuel consumption. Gradual rationalization of fossil-fuel subsidies, introduction of carbon pricing mechanisms, and implementation of environmentally corrective taxation policies can create incentives for cleaner production and sustainable consumption patterns. These measures should be designed with careful consideration of

distributional impacts to maintain social and economic stability.

Overall, achieving sustainable economic growth in Pakistan requires an integrated policy framework that simultaneously

advances energy transition, financial sector reform, and environmental regulation.

### **Limitations and Future Research**

Despite its contributions, this study is subject to certain limitations. The analysis relies on aggregate annual data, which may obscure sectoral and regional heterogeneity in environmental impacts. Furthermore, while ecological footprint provides a comprehensive measure of environmental pressure, it does not capture all dimensions of environmental quality, such as localized air pollutants or biodiversity loss. Future research may extend this framework by incorporating sector-specific data, alternative environmental indicators, or nonlinear modeling approaches to further explore the complex dynamics among financial development, energy transition, and environmental sustainability.

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