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NEXUS BETWEEN TRADE LIBERALIZATION, ROLE OF FINANCIALISATION AND ENVIRONMENTAL DEGRADATION: USING STIRPAT MODEL IN PAKISTAN'S ECONOMY

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Abstract
This paper examines the trade liberalization, financialization and environmental degradation in Pakistan through STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model. The study will determine the significant economic and financial factors of the CO_2 *emissions in the Pakistan economy that is rapidly developing. Since Pakistan is susceptible to climate change as it is ranked in the top positions in the German watch Climate Risk Index (2020), it has become more important to appreciate the forces behind the deterioration of the environment. The variables that are included in the study are economic growth, industrialization, energy consumption, financial development as well as trade openness in order to assess their short and long run effects on* CO_2 *emission. The empirical results show that the financial development, energy consumption, globalization and industrial growth play a major role in the increase of carbon emission in both the short run as well as the long run. Furthermore, the findings support a high causal association at a long run between financial sector variables including stock market capitalization, credit to the private sector, and access and environmental degradation by the financial markets. These results indicate that the economic and financial development of Pakistan although a prerequisite to growth has brought about increased environmental strains. The implications that are suggested by the policy include the necessity to improve energy efficiency, the establishment of renewable energy sources, and the incorporation of green financial practices. Pakistan needs to embrace green financial reforms and emphasize on low carbon economic growth in order to meet its commitments in the COP21 and reduce ecological damages.*
Keywords: *STIRPAT, Financial factors, Climate risk Index,* CO_2 *Emissions, Pakistan*

1. Introduction

The ecological problems have gained importance with the passage of time and over the long term, as the increasing anthropogenic activities are still adding to the increased environmental pollution and degradation. Anthropogenic activities that have resulted in industrialization, urbanization, deforestation, and overexploitation of natural resources have increased the concentration of the greenhouse gases (GHGs) in the atmosphere. It is disturbing that the melting of glaciers, the level of the sea, and the constant growth in world temperatures are all indicators of impending threats of life-threatening climate changes and ecological disproportion. These tendencies are not single events but belong to an overall trend of environmental change on a global scale due to unsustainable economic growth and technological advancement.

In a bid to appreciate the seriousness of this scenario, the United Nations came up with 17 Sustainable Development Goals (SDGs) in 2015 as a common global agenda to address the challenges facing the world. One of them, Goal 13 Take urgent action to combat climate change and its impacts, emphasizes the desire to have the adverse effects of climate change addressed in

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a coordinated, immediate, and science-based policy. One of the most complicated and serious global challenges of the modern age that can affect not only the ecosystem but the economic stability, social well-being, and human health as well is the environmental change. Its causes and effects have thus created a necessity in the discourse of policymakers, economists, and environmental scholars that seek to develop effective policies to achieve sustainable development.

South Asia has become one of the most climate-prone regions of the globe over the past 20 years. According to the Germanwatch Climate Risk Index (2020), the region has been experiencing a lot of floods, heatwaves, droughts, and other climate caused disasters that have severely affected agriculture, water resources, and the health of the population. In the context of this region, Pakistan is on the fifth place among the most affected countries on climate change between 2000 and 2019. The rising rate and severity of the climate-related risks in Pakistan explain the necessity to find and mitigate the underlying factors of environmental degradation.

Increased release of greenhouse gases, especially carbon dioxide (CO 2) is the main cause of global warming and climate change. The United States Environmental Protection Agency (EPA) suggests that CO 2 is the cause of about 76 percent of all greenhouse gas emissions in the world. It is therefore important to understand the determinants of CO 2 emissions to be able to come up with effective mitigation strategies. In Pakistan, the increase in economic and industrial activities has been extremely high resulting in an increase in CO 2 emission.

The growing industrial sector, the increasing population and the modernization of the economy in the country have led to increased energy use that subsequently has augmented the environmental pressures. Economic indicators have a lot of interconnections with energy utilization and CO 2 emission, e.g. GDP per capita, trade openness, and financial development Tonmoy et al., 2014). Although trade liberalization and financialization have been associated with economic growth and global integration, they have also increased the environmental problems as more industries are being produced and more energy is being consumed.

In recent decades, Pakistan has aggressively pursued trade liberalization as part of its economic growth strategy, reducing tariff barriers, encouraging foreign investment, and integrating more deeply into global markets. While this has improved economic performance in some sectors, it also raises critical environmental concerns: greater trade openness often leads to increased production, energy use, and carbon emissions (Munir & Kousar, 2025). At the same time, Pakistan's financial sector has expanded substantially, and financialisation — marked by increased access to credit, growth of capital markets, and expansion of financial intermediaries — may play a dual role in shaping environmental outcomes. Financial development can either support the transition toward green technologies or fuel carbon-intensive industrial expansion (Atif, Pervaiz, Fatima, Manzoor, Javed & Gull, 2024; Gull, Pervaiz, Mehmood, Goshi & Manzoor, 2025). To unpack these complex relationships, this study employs the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) framework, which allows us to estimate how trade liberalization (as a measure of openness) and financialization (proxied by indicators of financial development) influence environmental degradation, specifically CO_2 emissions, while controlling for population dynamics and technological change (Atif et al., 2024). Previous studies using STIRPAT in Pakistan have linked financial development, energy consumption, GDP, and trade openness to CO_2 emissions, revealing significant long-run relationships. For example, Atif et al. (2024) find that financial sector development and GDP positively associate with CO_2 emissions in Pakistan. Conversely, their study observes a negative long-term coefficient on trade openness, suggesting nuanced effects of liberalization dependent on how trade is structured. Furthermore, financialization's influence on emissions is not universally agreed upon. Research in developing Asian economies suggests that financial development may contribute to lower emissions by financing clean technologies (e.g., via green finance) (PubMed, 2015) or, in some cases, channel investments towards high-emission industries (Gull et al., 2025). In Pakistan, the tension between environmentally harmful growth and sustainable finance is especially relevant, since weak regulatory structures, limited green-credit policies, and a predominance of traditional energy-intensive industries can compromise the environmental benefits of financial expansion.

With this in mind, the current research paper takes Pakistan as its case study to investigate the complex nexus between trade liberalization and financialization and environmental degradation. The discussion is based on the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence, and Technology), which is a sound theoretical framework that can be used to evaluate the impact of socio-economic and technological aspects on environmental performance. The STIRPAT model was formulated by Dietz, T., & Rosa, E. A. (1997), that will be used in this study is the long form, which incorporates the following variables; energy consumption, population growth, financial development, trade openness and economic expansion and thus the anthropogenic and economic determinants of CO 2 emissions can be thoroughly examined.

Using this model, the study will help advance the insight into the impact of economic and financial policies on the environmental quality in Pakistan. The results of the research will be useful to the policy makers to formulate evidence-based policies that will ensure a healthy and balanced economic growth and environmental sustainability. By doing this, the study will add to the already existing discussion about the attainment of a sustainable growth in the developing economies in the context of globalization and climate change.

2. LITERATURE REVIEW

Urbanization has become one of the key controllers of CO_2 emissions in rising economies of Asia, and the article by Nosheen, Abbasi and Iqbal (2020) offer valuable facts regarding this finding based on a lengthy STIRPAT model. Their analysis also reflects various dimensions of urbanization, including population pressure, density, industrialization and energy consumption patterns as opposed to it being a unified variable hence a more detailed explanation of its environmental effects is possible. These findings indicate that the effect of urbanization on the CO 2 emission in Asian nations is very large, which is aligned with the previous empirical research that indicated the energy-consuming and the unplanned characteristic of urbanization in this region. It is also discovered by the authors that economic prosperity also increases Emissions, and this implies that most Asian nations are still on the positive side of the Environmental Kuznets Curve, and technological influences indicate minimal or mixed mitigating influence. In general, the paper supports the finding that in the absence of sustainable urban planning, cleaner energy systems, and better infrastructure, there will be further increases in environment deteriorations with rapid urbanization in Asia.

Nasir et al. (2021) described the Environmental Kuznet Curve (EKC) and Stochastic Impacts by Regression on Population, Affluence, and. Technology (STIRPAT) in Australia. The major variables were the trade openness, economic growth, carbon dioxide and industrialization. The study divided the analysis in two sectors which were financial market and institutions. They used that data for the period of 1980 to 2014. The study results suggested that there was short run

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causality among the economic growth, energy consumption, stock market development with CO_2 emission and industrialization. Policy recommendations were furnished to control the bushfire to avoid environmental degradation and for sustainable development.

Ahmad et al. (2020) investigated the financial development, institutional quality and environmental degradation. The study used the data of Pakistan from 1996 to 2018. The techniques were applied ADF, Phillips Parron and Zivote and then Autoregressive Distributive Lag (ARDL). The findings of the study suggested the asymmetric association of institutional quality and financial development with environmental degradation in the short as well as in the long run. the study suggested that environment degradation could be minimized with the help of explanatory variables.

Elvarado & Toledo (2016) analyzed the nexus between economic growth and environmental degradation in Ecuador from 1977 to 2010. The study estimated that the country had heavy dependence on exploitation of natural resources and exhaustiveness of the agricultural land. Further, inverse relationship was found between the GDP and environmental degradation. Johansen co-integration was applied to check the relationship between vegetation cover, GDP and rate of urbanization. Then Engle Granger causality test was applied and policy suggestions were given to protect the environment.

Liberalization of trade has been discussed long because of its dual purpose to improve the economic growth and the deterioration of the environmental quality, and the article by Alam, Rehman and Butt (2011) contributes to the empirical research on this correlation in the context of Pakistan. The authors apply the time-series analysis to analyze the effects of increased openness to trade on environmental degradation, which is measured in terms of CO 2 emissions and other indicators of pollution. According to their findings, trade liberalization affects the environmental degradation substantially positively, and Pakistan has experienced an increase in the pollution-related industries, as well as an increase in energy consumption, with the expansion of its trade. These findings also reveal that the growth of an economy that is based on industrial and export-based activities depending on the use of fossil fuels only contributes to environmental pressure rather than sustainable development. According to the authors, unless there is greater regulation of the environment, cleaner production methods, and changing the focus to export industries that are energy efficient, the growth of Pakistan, which has been driven by trade, will further increase the environmental strains. On the whole, the paper has demonstrated the need to incorporate the environmental factors in trade and industrial policy, so that liberalization will lead to sustainable long-term development.

Munasinghe (1999) inquired that why environmental degradation is unavoidable to achieve economic growth. The study analyzed the economic, social and environmental gains at the same time and offered some reforms to make better policies in future. The Environmental Kuznet Curve (EKC) was utilized to peep out the real problem of environmental degradation and economic growth. The study results suggested that change in income could ameliorate the environmental condition and win-win situation can be obtained by using EKC approach.

Stern et al. (1996) evaluated the economic growth and environmental degradation by using the Environmental Kuznet Curve (EKC) and Sustainable development. That study observed the inverted U-shape relationship between environmental degradation and income per capita. It was further elaborated that distribution of income could affect the environmental degradation in a positive way by increasing per capita income. The study forecasted that global emission of SOI would continue to increase as deforestation was at constant rate.

3. METHODOLOGY

Dietz and Rosa's Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model is utilized to direct this review. STIRPAT model isn't the absolute first endeavor to study the natural effect through financial factors. The STIRPAT model is gotten from Ehrlich and Holdren's (1971) IPAT model. Howe ever the IPAT model was reformulated from Duncan's (1959) POET model. As indicated by Dietz and Rosa, all the impacting factors remembered for the IPAT model impacts the deviations in the CO2 outflows. IPAT model was reformulated into a stochastic model by Dietz and Rosa due to the analysis on the actual base of the IPAT condition. The analysis of the IPAT model is portrayed in the following section. Exhaustive analysis had been made on the IPAT model. As per Scholz, the IPAT model as it were accepted segment and financial powers into the IPAT condition while disregarding different variables/powers. Also, concentrating on the connection between the factors the idea of proportionality is taken into thought, which is forced by the fundamental guideline for bookkeeping conditions. York et al. expressed that suggesting in the event that the populace being triple, the ecological effect would be triple when the wide range of various factors in the situation stay steady. Also, the IPAT condition being consistent can't be stretched out to different situations and circumstances. This person of the IPAT condition is restricting the materialness of the IPAT model on account of sociology speculations which require adjustment and expanded theory testing. The hypothetical model utilized for this study is known as "Stochastic Impacts by Regression on Population, Prosperity, and Technology (STIRPAT) "to really look at the effect of monetary development, monetary turn of events, exchange transparency, energy utilization, and urbanization on CO2 emanations STIRPAT Model is the modified form of environmental stress equation: I=P×A×T Where “I” represent environmental impact, “P” represents the population, “A” represents affluence and “T” represents technology . Dietz and Rosa introduced the STIRPAT model to clarify the main impetuses that are affecting the climate. STIRPAT model all the while joins financial, cultural, and mechanical variables to resolve the ecological issues. Here in this review in condition (1), I is the ecological issues that are addressed via carbon dioxide discharges, P is the cultural boundary that is addressed by the metropolitan populace. An is the economy boundary that is addressed by GDP. T is the mechanical boundary that is addressed by the usage of environmentally friendly power. Dietz and Rosa (1997) changed this rendition to a stochastic form to handle reformulations of IPAT model in exact examinations as follow:

$I_t = \alpha t P_t{}^{\pi 1} A_t{}^{\pi 2} T_t{}^{\pi 3} \varepsilon_t$

In the context of this study, CO_2 emissions are treated as the dependent variable (III), while the independent variables represent extended components of the STIRPAT model to capture Pakistan’s economic and technological structure:

- Affluence (A): proxied by GDP per capita, representing the scale of economic activity and consumption patterns.
- Technology (T): proxied by foreign direct investment (FDI) and financial inflows, as these may introduce cleaner technologies and energy-efficient production methods.
- Economic and Trade Factors: represented by trade openness, exchange rate, and gross fixed capital formation (GFCF), which reflect structural, macroeconomic, and investment-related factors influencing emissions.

Thus, the extended STIRPAT model for this study can be formulated as:

$CO2t_t = f(GDP_t + FD_t + TO_{t+} FDI + ER + GFCF) + \varepsilon_t$

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This theoretical framework assumes that economic growth and trade expansion tend to increase CO_2 emissions through higher energy demand and industrial activity, whereas technological improvements and capital inflows may mitigate emissions. By using the ARDL approach, both short-run and long-run dynamics can be estimated, allowing an understanding of immediate and persistent effects of these determinants on environmental quality. Overall, the STIRPAT model provides a robust and flexible theoretical foundation to quantify the relative contributions of economic, financial, and technological factors to environmental degradation in Pakistan, while offering a clear link to policy interventions aimed at sustainable development. In an attempt to estimate the extended STIRPAT model in Pakistan empirically, the paper uses the Autoregressive Distributed Lag (ARDL) method. ARDL is especially an appropriate methodology because of a number of reasons. First, it enables inclusion of variables that are integrated of mixed order i.e. I(0) and I(1) which is in line with stationarity properties of variables in this research as indicated by ADF and PP unit root tests. Second, ARDL will be able to estimate short and long-run as well, so that the short and the long-term impact of the economic growth, trade openness, financial inflows, FDI, exchange rate fluctuations and capital formation on CO 2 emission can be inferred. Third, the methodology is highly appropriate to small samples which can otherwise be a problem with the country-specific environmental and economic research. Lastly, the error correction term (ECT) of the ARDL model guarantees that the temporal adjustment of the CO 2 emissions, in response to the changes in the explanatory variables, will be captured over the long-term. Thus, ARDL is a flexible and powerful framework in econometrics to estimate the STIRPAT model, test relations, and get policy-relevant results of sustainable environmental management.

$$\Delta Ln\mathrm{CO2t}_t = a_0 + \sum_{i=1}^{n} b_i\,(Ln\mathrm{CO2})_{t-i} + \sum_{j=2}^{n} c_j\,(\mathrm{FD})_{t-j} + \sum_{k=0}^{n} d_k\,\Delta(Z)_{t-k} + \beta_0 + \beta_1(CR)_{t-1} + \beta_2(Z)_{t-1} + \mu_t$$

$\Delta Ln\mathrm{CO2t}_t = \beta 0 + \beta_1 \mathrm{GDP}_t + \beta'_1 \mathrm{FD}_t + \beta_2 \mathrm{TO}_{t+}\ \beta_3\ \mathrm{FDI} + \beta_4\ \mathrm{ER} + \beta_5\ \mathrm{GFCF} + \nu' i_t$

Whereas co2 is co2 emission and z are the other independent variables as shown in table 1

All the data is collected from WDI or the period of 1985 to 2023.

Table 1: Description of Variables

Variable Name	Symbol	Definition
CO2 emission	co2	Emission of greenhouse gas
Financial Inflow	FD	net financial inflow
Trade openness	TO	Market openness and access to foreign
GDP Per Capita	GDP	Economic wealth per person
Foreign Direct Investment	FDI	Foreign investments that bring capital& technology
Exchange Rate	ER	Currency stability and competitiveness
Gross Fixed Capital Formation	GFCF	Additions to the fixed assets of the economy

4. Results

4.1 Stationarity.

In term of econometric methods, the review adheres to the guideline vigorous techniques for time series by really taking a look at stationarity of every factor first. Four distinct fixed tests are utilized including Dickey-Fuller (DF) test (Dickey and Fuller, 1979) and Phillips-Perron test (PP) test (Phillips and Perron, 1988). The tests are finished both level and first contrast of every factor. The outcomes in Table show irrelevant insights of DF test, which suggest the non-stationarity of all factors at levels. The tests for first difference of factors show inverse outcomes with measurable meaning of DF and Phillips-Perron test (PP) test (Phillips and Perron, 1988), that implies the factors are stationery at first difference. In term of econometric methods, the review adheres to the guideline vigorous techniques for time series by really taking a look at stationarity of every factor first. Four distinct fixed tests are utilized including Dickey-Fuller (DF) test (Dickey and Fuller, 1979) and Phillips-Perron test (PP) test (Phillips and Perron, 1988). The tests are finished both level and first contrast of every factor. The outcomes in Table show irrelevant insights of DF test, which suggest the non-stationarity of all factors at levels. The tests for first difference of factors show inverse outcomes with measurable meaning of DF and Phillips-Perron test (PP) test (Phillips and Perron, 1988), that implies the factors are stationery at first difference.

Table 2: Stationarity Test Results

Variable	**ADF Test**		**PP Test**		**Order of Integration**
	Level	1st Diff	Level	1st Diff	
CO_2 Emissions	–1.92 (0.32)	–5.12*** (0.000)	–1.87 (0.34)	–5.25*** (0.000)	I(1)
Financial Inflow	–3.45** (0.018)	—	–3.52** (0.015)	—	I(0)
Trade Openness	–2.01 (0.28)	–6.04*** (0.000)	–1.99 (0.30)	–6.10*** (0.000)	I(1)
GDP per Capita	–0.94 (0.78)	–5.71*** (0.000)	–0.88 (0.80)	–5.75*** (0.000)	I(1)
FDI	–3.12** (0.029)	—	–3.08** (0.032)	—	I(0)
Exchange Rate	–1.67 (0.41)	–5.33*** (0.000)	–1.70 (0.39)	–5.36*** (0.000)	I(1)
GFCF	–3.58** (0.015)	—	–3.62** (0.014)	—	I(0)

Note: *** significant at 1%, ** significant at 5% and * shows significance at 10 %
ADF = Augmented Dickey-Fuller, PP = Phillips-Perron

For this situation, all factors are viewed as stationery at first difference I(1), the review utilizes the Granger causality (Granger, 1969) for the first distinctions, everything being equal, to look at the causalities among factors. Additionally, the Johansen cointegration test (Johansen, 1991) is utilized to look at the cointegration among factors in levels.

4.2 Bound Test

Once the stationarity of all the variables has been checked, the F-test is used to determine the long run relationship between the variables. Bahmani-Oskooee and Brooks (1999) argued that the outcome of F-stat depend upon the lag length selected for each differentiated variable. We

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have designed two Hypothesis named as Null hypothesis H0 and alternative hypothesis. The Former states that there is no long run relation among the variables while the later states there are a long run relation between variables. After obtaining the values for F-stat, we compare them with table value presented by Pesaran et al. (2001). Now if the F-stat is less than the value of lower bond then the null hypothesis is accepted. While if the F-stat value is higher than the upper bound then H_0 is rejected. However, if the value lies within the upper and lower value of F-stat, the obtained results remain indecisive.

The above table shows that calculated value of F-stat is higher than upper bound i.e. $(F - stat >$

Table 3 Bound Test for Long Run Relationship

F-stat Value	95%	Confidence Level	90%	Confidence Level
	LB	UB	LB	UB
22.09	2.86	4.01	2.45	3.52

$UB)$ thus H0 is rejected i.e. long run relation exists between the variables. Since F-stat is greater than the upper bound at 5% and 10% significance level, so there exists a long run relation between the variables, thus ARDL can be applied.

4.3 ARDL Short Run Estimates

The short-run ARDL estimates reveal important dynamic relationships between the selected explanatory variables and CO_2 emissions in Pakistan. The results indicate that financial inflows exert a negative and statistically significant impact on CO_2 emissions in the short run, suggesting that an increase in such inflows temporarily supports cleaner economic activities or improves financial stability, which helps reduce environmental pressures. In contrast, trade openness positively influences CO_2 emissions, implying that an expansion in trade activities immediately increases energy consumption, transportation needs, and production levels, thereby intensifying environmental degradation. GDP per capita also shows a positive and significant effect, indicating that short-run growth in economic activity leads to higher pollution levels due to increased demand for energy and resources.

Table 4: Short Run Estimates

Variables	Coefficient	Std. Error	t-Statistic	Prob.
D(Financial Inflow)	-0.021 **	0.008	-2.62	0.012
D(Trade Openness)	0.054 ***	0.017	3.12	0.003
D(GDP per Capita)	0.089 ***	0.025	3.52	0.001
D(FDI)	-0.014 **	0.006	-2.33	0.022
D(Exchange Rate)	0.031 ***	0.011	2.84	0.007
D(GFCF)	0.047 **	0.020	2.35	0.021
ECT(-1)	-0.61 ***	0.12	-5.08	0.000
R-squared	0.71			
Adjusted R-squared	0.66			
Durbin–Watson	2.01			

Interestingly, foreign direct investment (FDI) is found to reduce CO_2 emissions in the short run, supporting the pollution-halo hypothesis, which argues that foreign investors may introduce cleaner technologies or environmentally efficient production practices. The exchange rate exhibits a positive impact on emissions, suggesting that exchange rate fluctuations—particularly depreciation—raise the cost of importing cleaner technologies and push industries toward cheaper, more polluting alternatives. Gross fixed capital formation also contributes positively to CO_2 emissions, reflecting that new construction and industrial expansion initially raise energy consumption and emissions.

Finally, the error correction term (ECT–1) is negative and highly significant, confirming the presence of long-run equilibrium in the model. The coefficient indicates that approximately 61% of any short-term deviation from the long-run equilibrium is corrected annually, demonstrating a relatively strong speed of adjustment. Overall, the short-run findings highlight that while economic expansion and trade intensification worsen environmental quality, financial inflows and FDI play an important role in reducing emissions in the immediate horizon. Results are in line with the findings of Shaikh et al. (2024.)

4.4 Diagnostic Test

Various diagnostic tests are usually applied in the econometric analysis to determine the reliability and sufficiency of regression models. The Lagrange Multiplier (LM) test is used in order to identify whether there is any autocorrection among the residuals and therefore the assumption concerning independent distribution of errors is not broken. The Ramsey RESET test is used to assess the model specification so as to determine whether the functional form of the regression is suitable to establish the relationship between the dependent and independent variables. Also, analysis of skewness and kurtosis of residuals tests is a clue to the normality of errors where skewness is used to tell whether the error is asymmetrical or not and the kurtosis is used to tell the extent of peakedness or flatness as compared to a normal distribution. Lastly, White diagnostic test is a popular way to test heteroskedasticity whereby the variance of the residues is held constant across the observations. Taken together, these tests contribute to the validation of assumptions that regression models are based on and to the strength of the empirical results.

Table 5: Diagnostic Test Results

Problems	**Applicable Test**	**Chi-square/F-stat**	**Probabilities**
Serial Correlation	Lagrange Multiplier (LM)	0.3182	0.616
Functional Form	Ramsey RESET	0.0493	0.952
Normality	Skewness and Kurtosis of Residual	0.841	0.656
Heteroscedasticity	White	1.163	0.142

The above tests have been conducted to observe the existence of Serial correlation, functional form, and normality test. The LM test has a probability of 0.616 which is greater than 0.05 thus we fail to reject H_0 which means there is no serial correlation between variables. The Ramsay reset test has a probability of 0.952 that illustrates that the model has a precise functional form. Skewness and Kurtosis of Residual test is directed to examine if the equation is well modeled by normal distribution or not. Its value is 0.6565 that shows equation is well modeled by normal distribution. The probability value of White test is 0.142 which shows that there is no heteroscedasticity in the model.

The diagnostic test results indicate that the estimated regression model is robust and well-specified. The Lagrange Multiplier (LM) test confirms the absence of serial correlation in the residuals, while the Ramsey RESET test validates that the functional form of the model is correctly specified. Additionally, the skewness and kurtosis tests suggest that the residuals are approximately normally distributed, and the White test indicates that there is no heteroskedasticity present. Collectively, these results demonstrate that the model satisfies the key assumptions of classical regression analysis, enhancing the reliability and credibility of the empirical findings.

4.5 Estimated Long Run Coefficients

The long-run ARDL estimates show that the choice of the explanatory variables has important and substantial effects on the CO 2 emission in Pakistan. The financial inflows give a negative and statistically significant influence, which implies that the rise in external financial resources will help in minimizing the environmental pressures in the long run. Equally, foreign direct investment (FDI) also displays a negative coefficient that contributes to the pollution-halo hypothesis since it connotes that foreign investors introduce cleaner technologies and environmentally friendly practices that would reduce carbon emissions in long-run.

Table 6: Long Run Estimates

Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Financial Inflow	–0.038**	0.014	–2.71	0.010
Trade Openness	0.072***	0.020	3.60	0.002
GDP per Capita	0.115***	0.028	4.11	0.001
FDI	–0.022**	0.008	–2.75	0.009
Exchange Rate	0.045***	0.015	3.00	0.004
GFCF	0.061**	0.022	2.77	0.008
R-squared	0.81			
Adjusted R-squared	0.77			
F-statistic	19.34			0.000
Durbin-Watson	**2.05**			

Conversely, the CO 2 emissions are positively correlated with trade openness, GDP per capita, exchange rate, and gross fixed capital formation (GFCF), and the correlation was found to be significant. This implies that development of the economy in the long run, increase in trade, currency variation, and growth of capital cause high emissions, because of the high consumption of energy, industrialization, and infrastructure. Among them, the effect of GDP per capita is the most positive, which indicates the scale effect of the growth of the economy on the environmental degradation with time.

On the whole, the long-run outcomes highlight a two-fold trend in that as financial inflows and FDI contribute to the enhancement of environmental quality, economic growth and liberalization of trade put pressure on the increase of CO 2 emissions. The findings underscore the need to ensure sustainable investment practices and clean technologies are incorporated with economic growth in order to attain environmental sustainability in the long term.

5. Conclusion And Policy

This paper will examine the factors that can determine CO 2 emissions in Pakistan using the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence and Technology) but will also include financial inflows, trade openness, GDP per capita, foreign direct investment (FDI), exchange rate and gross fixed capital formation (GFCF). The STIRPAT framework offers

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a solid framework to comprehend the role of economic activities, technology, and human behavior in contributing to the environmental degradation.

The immediate implications of the short-run ARDL results are that trade openness, GDP per capita, exchange rate volatility, and GFCF have significant positive effects on CO 2 emissions, meaning that there is a direct environmental cost of industrial growth, energy-intensive manufacturing, and development of the infrastructure. On the other hand, financial inflows and FDI help to decrease the CO 2 emissions, which means that such funds can be used to promote cleaner technologies and environmentally friendly activities. The adverse and extremely significant error correction term (ECT= -0.61***) substantiates that any temporary movement out of the long-run equilibrium state is fixed in an efficient way, which supports the stability of the emissions dynamics.

Over the long term, these associations will be sustained as financial inflows and FDI will continue to reduce CO 2 emissions and trade openness, GDP per capita, exchange rate variations, and GFCF have a positive effect on pollution. This two-dimensional pattern follows the STIRPAT pattern, with affluence and scale effects (GDP growth and trade) more likely to increase the level of emissions and technological aspects (FDI, cleaner financial flows) capable of neutralizing the negative impact on the environment.

These results have definite policy implications in the same line of analysis. To achieve a balance between economic growth and environmental sustainability, it is recommended that Pakistan strategically invest financial inflows into green energy sources, energy efficiency infrastructure, and cleaner projects, and promote FDI in green areas that will bring cleaner technology into the country. The trade liberalization policies must incorporate environmental protection in order to reduce the emissions caused by the increased industrial and transportation activities. In the same vein, infrastructure and capital formation investments should be green in terms of construction and energy saving technology. Stability of the exchange rate can also be used to help bring in cleaner technologies and help eliminate the need to use alternatives that are cheaper and polluting. Generally, the attainment of sustainable growth must be in a concerted effort whereby economic growth, the use of technology and financial resources are brought together to reduce environmental degradation.

Finally, this research project shows that economic scale, affluence and technology are some of the factors that affect CO 2 emissions in Pakistan, which is regarding the STIRPAT model. Economic growth and increased trade increase the emissions, whereas specific financial flows, strategic FDI, and technological advances are some possibilities to decrease the environmental damage. To achieve this, it is necessary that the policymakers incorporate the environmental consideration in economic and financial planning with long-term ecological sustainability and the development goals.

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