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Testing the Pollution Haven Hypothesis in Pakistan: The Roles of Trade Openness, Foreign Direct Investment, Economic Growth, Energy Consumption, Investment, and Population in Environmental Degradation

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ABSTRACT:

Environmental degradation has emerged as one of the most significant global challenges confronting developing economies, particularly amid increasing trade integration and foreign direct investment (FDI). The Pollution Haven Hypothesis (PHH) states that multinational companies may shift pollution-intensive production activities to countries where environmental law and enforcement are comparatively less strict. Despite extensive empirical research, evidence on the validity of the PHH remains inconclusive, particularly for Pakistan. This research examines the long-run and short-run effects of trade openness, foreign direct investment, GDP growth, energy consumption, investment, and population growth on environmental degradation in Pakistan while testing the validity of the Pollution Haven Hypothesis. Yearly data for the period 1990–2025 are sourced from the World Development Indicators (WDI). Autoregressive Distributed Lag (ARDL) is employed to estimate both long-run and short-run relationships among the variables. The empirical outcomes confirm long-run associations among the selected variables. The findings indicate that foreign direct investment (FDI) has a negative and significant influence on CO_2 emissions, suggesting that foreign investment promotes environmental quality via cleaner technologies and efficient production practices. Consequently, the findings do not support the Pollution Haven Hypothesis in Pakistan. Energy consumption, trade openness, population growth, and investment were found to have positive and statistically significant effects on CO_2 emissions, indicating that these factors contribute to environmental degradation.

In contrast, economic growth (GDP) exhibits a negative and statistically significant relationship with CO_2 emissions. These findings suggest that while trade liberalization and foreign investment contribute to economic development, they also impose substantial environmental costs under a lenient environmental regulatory framework. The study's findings recommend strengthening environmental governance, promoting green foreign investment, encouraging clean production technologies, and implementing effective carbon mitigation policies to achieve sustainable economic development in Pakistan. The findings contribute to the environmental economics literature by offering updated insights into the connection among macroeconomic variables and environmental quality.

Keywords: Pollution Haven Hypothesis, ARDL model, Energy Consumption, FDI, GDP, Trade, CO2 Emissions.

1. INTRODUCTION:

Environmental degradation is considered as a serious challenge to sustainable economic growth in the twenty first century (Vial, 2026; Sharma et al., 2026). The rate of industrialization, growth of international trade, rising demand for energy, urbanization and globalization have contributed to the tremendous growth of GDP in both developed and developing countries (Khan et al., 2026). These, however, have also added to the environmental pressures, especially CO_2 emissions, which are the prime drivers of climate change globally (Chung et al., 2026). Global warming, loss of biodiversity, extreme weather events and environmental quality are some of the severe environmental consequences of the increasing concentration of GHGs, and hence environmental sustainability becomes a central concern of researchers and policy makers all over the world (Shivanna, 2022; Gulalai & Kanval, 2026). Global trade and Foreign Direct Investment (FDI) are among the drivers that have garnered a lot of attention in the environmental economics literature (Kumar et al., 2025; Caetano et al., 2024). Economic globalization has facilitated cross-border capital movements and expanded production networks, enabling multinational corporations to relocate production activities across countries in search of lower production costs and favorable investment environments (Su, 2025; Akusta, 2026). While trade openness and FDI contribute substantially to Economic Growth (EG), employment generation, technological advancement, and capital accumulation, they may simultaneously increase environmental degradation if production activities are concentrated in pollution-intensive industries operating under weak environmental regulations (Amponsah et al., 2025). This concern forms the basis of the Pollution Haven Hypothesis (PHH), which claims that big corporations often shift environmentally harmful manufacturing processes from nations that impose strict environmental regulations to emerging nations where environmental standards are comparatively less restrictive (Taylor, 2004; Gill et al., 2018).

However, if developing nations set environmental standards below their own level to attract global investment, they are sometimes accused of offering a refuge for pollution. Several researchers found that pollution havens failed to really exist. However, the classic theory of endowments shows that polluting activities are usually capital-intensive and therefore localize in wealthy countries where capital is abundant (Neumayer, 2016). Due to low environmental standards, free trade and multinational corporations may eventually relocate the production of their pollution-intensive products to developing nations, giving those nations a comparative advantage in pollution-intensive industries and turning them into havens for global dirty businesses, according to PHH. While poor countries may suffer, industrialized countries are thought to gain from trade in terms of environmental quality. Three metrics are used in the pollution haven theory:

- Moving highly polluting enterprises from industrialized countries with strict environmental laws to developing nations with laxer rules.
- The export of hazardous waste produced in developed countries to developing nations for treatment, storage, or disposal.
- Unrestrained extraction of non-inexhaustible assets in developing nations by multinational corporations engaged in assembling oil and oil goods, timber, wood assets, and so forth.

The World Bank (2016) states that burning fossil fuels and producing cement are the main sources of carbon dioxide (CO2) emissions. To lower compliance costs, multinational corporations may move pollution-intensive production operations to nations with laxer environmental laws under the PHH. Because larger emissions may imply the movement of environmentally damaging production to nations with laxer environmental regulations, CO2 emissions are employed as the dependent variable and as a proxy for testing the PPH. Our variable, carbon dioxide emissions, is selected to serve as a stand -in for pollution levels, which may also indicate environmental policy neglect. Since CO2 accounts for 58% of the world's gas, it is the most significant greenhouse gas (Shahzad et al., 2017).

According to the ‘World Climate Risk Index 2015, Pakistan is among the top ten nations that have been adversely affected economically due to serious energy crises. Weak environmental protection laws have been a concern for the government’. In 2005, Pakistan authorized controls on environmental corruption through the 'National Environmental Policy' (NEP). The primary goal of the NEP is to protect, preserve, and restore Pakistan's environment to improve residents' standard of living through practical development.

According to the World Bank (2015), Energy Consumption (EC) refers to the use of primary energy before it is converted into final energy products for end users.' As economies expand, the demand for energy increases to support industrial production, transportation, and other economic activities. However, greater EC, particularly from fossil fuel sources, contributes significantly to environmental pollution and rising carbon dioxide (CO_2) emissions. The continuous growth in energy demand poses serious environmental challenges. It highlights the need to adopt renewable and sustainable energy sources to ensure long-term economic development while reducing environmental degradation. EC has therefore raised '$CO2$ increase from 0.92 metric tons to 0.86 metric tons' above a similar amount. Energy utilization and carbon discharge are linked. Energy utilization discharges carbon dioxide emissions that are contaminating the environment. EC releases carbon dioxide emissions that are polluting the atmosphere. Increasing demand for machinery, vehicles, etc. will increase production and transport activities that increase EC.

FDI has three types of impact on environmental excellence in developing nations: first, it is scale impact, which might be positive if economic growth and intent in natural production help in finding environmental issues; otherwise, a negative scale impact happens when a country considers economic processes without environmental management. Second is technology impact once foreign investors use environmentally friendly technology. Third is approach impact, which can be ensured once a government has tight laws in place to ensure climate protection and further enforces foreign shareholders to follow such laws. Adverse strategy impact happens when there is rivalry among developing nations to attract FDI, and host governments relax environmental principles for FDI. FDI is sometimes undertaken in countries with fewer environmental laws to avoid wasting production value. FDI is undertaken in production sectors at the same time as it affects a country's environment. According to IBRD (2016), GDP per capita is a commonly used indicator of a country's economic performance and average income level. It is obtained by dividing the total gross domestic product by the midyear population. GDP per capita is generally reported in current U.S. dollars and is widely used to compare economic development and living standards across countries.

1.1 SIGNIFICANCE OF STUDY:

This research is also helpful in establishing the connection between pollution levels and FDI, so that policymakers could implement measures to prevent the deterioration of the environment before the results worsen. By examining the impact of economic variables such as trade, GDP, population, FDI, investment, and EC on $CO2$ emissions, it helps evaluate which of these variables affects the environment more significantly.

1.2 OBJECTIVES:

1. To examine the long-run and short-run effects of trade openness on environmental degradation in Pakistan.
2. To examine the impact of FDI on CO2 and evaluate whether the Pollution Haven Hypothesis is supported in the case of Pakistan.
3. To evaluate the influence of economic growth, EC, INV and population growth on environmental degradation.

2. LITERATURE REVIEW:

The section reveals the connections between FDI and CO2 emissions, GDP and CO2 emissions, EC and CO2 emissions, population and CO2 emissions, and trade and CO2 emissions. The relationship between GDP and CO2 emissions is known as the EKC; EG is connected with high CO2 emissions at first, and CO2 emissions tend to fall as an economy attains a threshold level of GDP growth. Halicioglu (2009) empirically studied the effect of ‘CO2 emissions on EC, GDP, and FDI in Turkey during 1960-2005 by using the ARDL test. The outcomes reveal long-run connections between the variables. The findings suggest that income is the fundamental variable in reducing CO2 in Turkey, followed by trade and energy utilization. Therefore, Solarin et al. (2017) evaluated the PPH from 1980 to 2012 in Ghana. Moreover, the study applied GDP, institutional quality, trade, EC, urbanization, and FDI as its key factors. The results show a long-run relationship among the factors. Moreover, GDP, population, FDI, trade, and financial development have a direct effect on CO2 emissions, whereas institutional excellence reduces CO2 emissions in Ghana. This shows that PHH is present in Ghana. Sun et al. (2017) investigated the presence of the PPH Postulate in China during 1980-2012 using an ARDL test. Also, they investigated the association among GDP, trade openness, financial development, FDI, and urbanization. The study used unit root tests and ARDL. The outcomes of ARDL show that, in the long run, there is a long-run association among GDP, FDI, trade, financial development, and CO2. The CO2 outcome will increase by 0.058% with a 1% rise in FDI, which demonstrates that PHH is present in China. Meanwhile, China may be considered an ideal for developing nations, and this examination helps developing nations.

In contrast, Tasri & Karimi (2019) examined the effect of energy utilization and FDI on environmental contamination during 1990-2014 by employing the Pooled Mean method. It was found that energy utilization had a direct impact, whereas FDI had an inverse impact on the environment. Moreover, the study found that higher discretionary cash flow, FDI, and national investment had a significant impact on EC in GCC. FDI has a negative influence on the environment through relative income. The results did not support the existence of pollution havens in the selected countries. The examination implies that nations appreciate the benefits of pollution-free, efficient, environmentally friendly power energy. The studies of Halicioglu (2009), Solarin et al. (2017), and Sun et al. (2017) show a positive correlation between FDI and

CO_2 emissions, which shows that PHH exists. At the same time, Tasri & Karimi (2019) show an inverse relationship between FDI and CO_2 emissions, which means that PHH does not exist.

Qureshi (2006) studied the PPH in Pakistan by investigating its trade and production patterns from 1975-2003. The study also examined whether Pakistan has exported more pollution-intensive products to OECD countries and whether strict environmental regulations influence Pakistan's exports of pollution-intensive goods in the importing nations. The results demonstrate that there has been a shift in export and output structures toward pollution-intensive production that corresponds to economic disparity. The findings appear to support the PPH and are suggested for an efficient environmental policy for property development and poverty alleviation. Furthermore, Hossain (2011) empirically studied the associations among CO_2 discharges, energy utilization, economic development, urbanization, and trade for the industrial nations from 1971 to 2007 by applying a unit root test. The author's findings demonstrate that there is a unidirectional short-run connection between trade and economic development and CO_2 emissions. The study shows that the long-term elasticity of CO_2 emissions with respect to energy utilization 1.218 is greater than the short-run elasticity of 0.598. This demonstrates that, over time, greater energy utilization in developed nations further contaminates our environment. In any case, regarding urbanization, trade, and economic development, air quality is expected to worsen in the long run. The studies recommend that conditions will worsen because of energy use in the long run, so Newly Industrialized nations should utilize solar energy instead of oil to reduce emissions. However, Shahbaz et al. (2012) used the Granger causality and bound test to experimentally examine the relationship between CO_2 emissions, trade, economic development, and EC in Pakistan between 1971 and 2009. The outcomes suggested that a long-term correlation exists between the factors, and the Environmental Kuznets hypothesis assumption exists. The presence of the Environmental Kuznets theory demonstrates the nation's struggle to eradicate CO_2 emissions and shows several accomplishments in controlling environmental degradation in Pakistan. Besides, the study found a one-way causal association between CO_2 emissions and economic growth. In both the short and long runs, energy utilization increases CO_2 emissions. In the long run, trade decreases CO_2 emissions, while in the short run it is irrelevant. The difference in CO_2 emissions between the short run and the long run is modified by around 10% annually.

Shahbaz et al. (2013) explored the association among trade, economic growth, energy utilization, and CO_2 emission during 1975–2011 in Indonesia. A unit root test was used for stationarity analysis, and the ARDL bounds test was employed for long-run association. The VECM studies the connection among the factors. The outcomes show that the factors are co-integrated. Ahmed et al. (2016) empirically investigated the relationship between CO_2 emissions, EC, GDP, population, and trade from 1971-2013 in five South Asian countries. For analyzing stationarity, the unit root test was used. The FMOLS test was used to analyze the long-run relationship between variables. The FMOLS test outcomes indicate that trade, population, environmental degradation, and energy utilization in the nations confirm the presence of the EKC between revenue and discharge. The variance decomposition test was used to examine the association among the variables. The outcomes demonstrate that there is bidirectional causality between trade and energy utilization and unidirectional causality between energy utilization, population, and CO2. The outcomes demonstrate that energy utilization and population density will increase in the long run. Furthermore, Shahzad et al. (2017) empirically examined the connection among carbon discharges, trade, energy utilization, and economic growth by applying an ARDL bounds test during 1971 to 2011 in Pakistan. The results show an inverted U-shaped association between carbon emissions and energy utilization.

Ozturk and Acaravci (2010) empirically investigated the connections among carbon dioxide emissions, Energy utilization, energy development, and the employment ratio in the Turkish economy from 1968 to 2005 by applying the ARDL bound test. The outcomes demonstrate that there is a long-run relationship between variables at the 5% significance level. The outcomes show that there is a long-run relationship between variables at the 5% significance level. This indicates that energy conservation strategies, for instance controlling energy utilization, are unlikely to have an adverse impact on actual productivity in Turkey. Moreover, Wang et al. (2011) empirically studied the impact of CO2 emissions, energy utilization, and EG in the Chinese economy. The data comprised 58 countries from 1990 to 2012. The results show that CO2 discharge has an inverse impact on EG, while energy utilization has a direct impact on economic growth.

Bilgili et al. (2016) investigated the legitimacy of the EKC theory using the dependent variable of CO2 outflows and independent variables, i.e., GDP and EC, in 17 OECD countries over the period 1977–2010. The study analyzed the EKC postulate to detect if (i) there exists an inverted U-shaped connection between CO2 outflows and GDP, and (ii) there is an inverse connection from renewables to CO2 discharges within the EKC framework. FMOLS and DOLS methods were employed. The findings supported the EKC hypothesis and indicate that GDP has a direct impact on CO2 emissions, and renewable energy consumption hurts CO2 emissions. The results show that the legitimacy of EKC does not rely on the income of individual nations, in which EKC theory contends that if nations completed (i) approaches, i.e., for reasonable and simple access to the power from inexhaustible resources and (ii Strategies to rise renewables resource by utilizing the enhanced technologies, they will have capacity to contribute for controlling carbon dioxide emission issue which rise their GDP.

Ertugrul et al. (2016) examined the association among CO2 emissions, GDP, and energy utilization trade in the top ten CO2 emitters among developing nations, i.e., Thailand, Malaysia, China, Turkey, South Africa, Indonesia, Mexico, Brazil, Korea, and India, during 1971–2011. The existence of the EKC theory is examined using unit root, ARDL, and Granger causality. The finding shows that (i) the factors show association for Thailand, Malaysia, China, turkey, south Africa, Indonesia, Mexico, brazil, Korea, India (ii) GDP, trade, energy utilization are the key factors of carbon discharges in long run, (iii) there exists relationship between the variables, (iv) EKC theory is confirmed for Korea, China, India and Turkey. Furthermore, Zhang et al. (2018) investigated the relationship between EC and CO2 emission. The study established the connection among economic growth, energy production, and CO2 discharge. The study recommended that contamination may be controlled by creating energy from sustainable sources, i.e., wind energy, geothermal, solar power, and hydropower instead of non-renewable sources.

Babalwa and Andrew (2017) evaluated the association between EG and CO2 production for the South African economy from 1970-2014. Quartile Regression methodology was employed for estimation. The findings revealed a direct relationship between GDP and CO2' at low levels, while a negative relationship at high levels. The study suggested that policymakers should continue to embark on energy efficiency programs that specifically target lower levels of carbon pollution.

2.1 RESEARCH GAP:

The majority of earlier research was conducted in industrialized nations and examined the association among macro variables (EC, GDP, FDI) and co2. Still, this study is carried out in developing countries like Pakistan and studies the connection among co2 and macro variables (GDP, population, trade, investment, EC, and FDI). This is essential.

in the deterioration of the environment. Also observe the presence of pollution haven in Pakistan and whether there is a direct association between CO2 and FDI.

3. DATA SOURCE AND HYPOTHESES:

The 'World Development Indicators (WDI)' annual time-series data for the years 1990–2025 are used in the study. Environmental degradation (co2 emissions) is measured by 'carbon intensity of GDP, expressed as kilograms of CO_2 equivalent (kg CO_2e) per constant 2015 US dollar of GDP', and serves as the dependent variable. The independent variables include 'gross domestic product (GDP) measured in current US dollars, FDI net inflows based on the balance of payments in current US dollars, energy use measured in kilograms of oil equivalent per $1,000 of GDP (constant 2021 PPP), trade openness measured as trade (% of GDP), population growth measured as the annual percentage growth rate, and investment, represented by gross fixed capital formation at constant local currency units (LCU)'. These variables are selected to examine their effects on environmental degradation in Pakistan. Figure 1 displays the conceptual framework used to examine the existence of PPH in Pakistan.

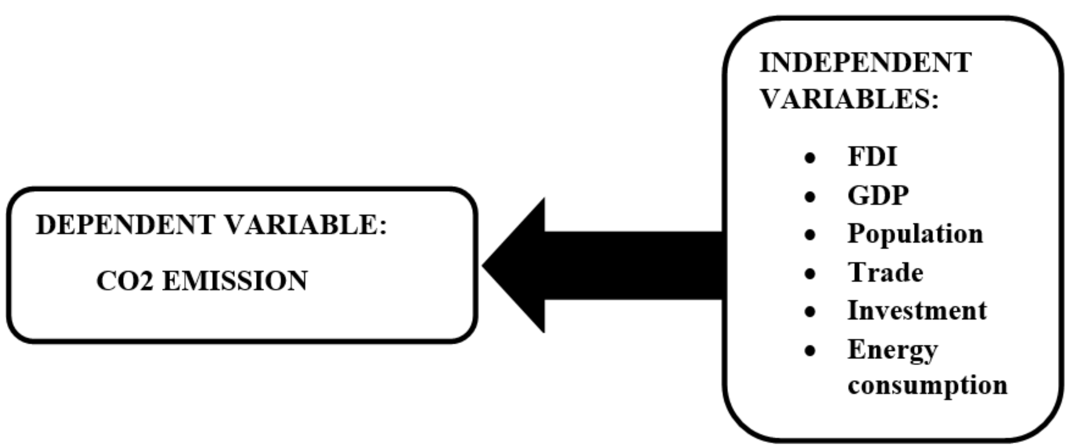


Figure 1: Conceptual Framework of the study

4. METHODOLOGY AND DISCUSSION:

The econometric approach to be employed is determined by the results of the unit root analysis. The order of integration for each variable is determined using the 'Augmented Dickey–Fuller (ADF)' test. If the variables are found to be non-stationary at their levels but become stationary after first differencing, or integrated of order one [I(1)], the Johansen cointegration approach is employed to examine the existence of a long-run equilibrium relationship among the variables. However, if the variables are integrated at a mixed order, with some stationary at level [I(0)] and others at first difference [I(1)], the Autoregressive Distributed Lag (ARDL) bounds testing approach is utilized to estimate both the long-run and short-run associations. Finally, the direction of causation between the variables in the study is ascertained using the Granger causality test. The results of descriptive statistics are present in Table A1 in Appendix.

4.1 CORRELATION STATISTICS:

Table 1

		CO2	EC	FDI	GDP	POP	TR	
CO2		1.000						
EC		0.781***	1.000					
FDI		-0.059	-0.390***	1.000				
GDP		-0.688***	-0.977***	0.455	1.000			
POP		0.617***	0.869***	-0.329***	-0.893***	1.000		
TR		0.111***	0.333***	-0.098***	-0.449***	0.525***	1.000	
Inv		-0.496***	-0.888***	0.629***	0.912***	-0.825***	-0.368***	1.000

Table 1 presents the 'Pearson correlation coefficients' among the study variables. CO2 emissions are positively correlated with EC (0.781), population growth (0.617), and trade openness (0.111), while they are negatively correlated with FDI (−0.059), GDP (−0.688), and investment (−0.496). Furthermore, EC shows a strong positive relationship with population growth (0.869) and a strong negative relationship with GDP (−0.977) and investment (−0.888). It is also negatively associated with FDI (−0.390) and positively related to trade openness (0.333).

However, FDI has a positive relationship with GDP (0.455) and investment (0.629), whereas it is negatively correlated with population (−0.329), trade (−0.098), EC (−0.390), and CO2 emissions (−0.059). GDP is positively correlated with investment (0.912) but negatively correlated with population (−0.893), trade openness (−0.449), EC (−0.977), and CO2 emissions (−0.688). Moreover, population growth is positively associated with trade openness (0.525) but negatively associated with investment (−0.825) and GDP (−0.893).

4.2 UNIT ROOT TEST:

Stationarity is an essential requirement in time-series econometrics because non-stationary data can produce misleading regression findings. This study uses the Augmented Dickey-Fuller to analyze each variable's integration order. The empirical results of the ADF test reveal a varied sequence of integration, with some variables stable at level (I(0)) and others stationary after initial differencing (I(1)). Since none of the variables are integrated of order two, I(2), 'the Autoregressive Distributed Lag (ARDL) bounds' testing strategy is thought to be the best method for estimating the long-run and short-run correlations among the variables.

Table 2

	Level	**Level**	**Level**	**Level**	**1st Difference**	**1st Difference**	**Order of Integration**
Variables	**Constant**	**Constant**	**Constant and trend**	**Constant and trend**	**Constant**	**Constant**	
Variables	**t-stat**	**Prob.**	**t-stat**	**Prob**	**t-stat**	**Prob**	
CO2	-1.555	0.494	-2.986	0.150	-5.237	0.0001	1(I)
EC	2.267	0.999	-2.985	0.151	-3.094	0.037	1(I)
FDI	-2.759	0.074					1(0)
GDP	-1.139	0.689	-2.417	0.364	-4.801	0.0005	1(I)
POP	-1.190	0.666	-4.156	0.013			1(0)
TR	-1.993	0.288	-2.233	0.458	-5.971	0.000	1(I)
Inv	-1.354	0.592	-3.092	0.124	-4.014	0.003	1(I)

4.3 BOUND TEST APPROACH

This study employs the Autoregressive Distributed Lag (ARDL) bounds testing technique created by Pesaran et al., (2001) to investigate the links among variables of interest. The unrestricted error correction representation of the ARDL model used in this study is expressed as:

$$\Delta (Co2)_t = a + \sum_{i=1} b\Delta (CO2)_{t-i} + + \sum_{i=1} c\Delta (GDP)_{t-i} + \sum_{i=1} d\Delta (FDI)_{t-i} + \sum_{i=1} e\Delta (TR)_{t-i} + \sum_{i=1} f\Delta (INV)_{t-i} + \sum_{i=1} g\Delta (EC)_{t-i} + \sum_{i=1} h\Delta (POP)_{t-i} + \beta_1(CO2)_{t-1} + \beta_2(GDP)_{t-1} + \beta_3(FDI)_{t-1} + \beta_4(TR)_{t-1} + \beta_5(INV)_{t-1} + \beta_6(EC)_{t-1} + \beta_7(POP)_{t-1} + \varepsilon_t \quad (1)$$

Where 'CO_2 represents carbon emissions, TR denotes trade openness, FDI is foreign direct investment, GDP represents economic growth, EC denotes EC, POP is population growth, INV represents investment, and ε_t is the error term'. The existence of a long-run relationship is ascertained using the ARDL bounds test. The calculated F-statistic is compared with the critical values provided by Pesaran et al. (2001). If the F-statistic exceeds the upper critical bound, the null hypothesis that there is no cointegration is rejected, confirming a long-term relationship. If the F-statistic is below the lower critical bound, the null hypothesis cannot be rejected. When the F-statistic falls between the two crucial values, the results are considered inconclusive. The computed F-stats are greater than I(1) at the 1%, 5%, and 10% significance levels, as Table 3 demonstrates. F-stats > upper bound crucial values 13.08045 > 3.59, 4, 4.38, 4.9 As a result, we reject the null hypothesis, which suggests that important macroeconomic variables and CO2 have long-term cointegration.

Table 3: ARDL Bounds Test

Bound Test F-stats: 13.08045	I(0)	I(1)
10%	2.53	3.59
5%	2.87	4
2.5%	3.19	4.38
1%	3.6	4.9

4.4 SHORT RUN AND LONG RUN COEFFICIENTS:

Table 4

Variables	**Short Run Coefficients**	**Short Run Coefficients**	**Long Run Coefficients**	**Long Run Coefficients**
Variables	**Coefficient**	**t-stats**	**Coefficient**	**t-stats**
D(FDI)	-2.56E-11***	-4.031	-2.75E-11***	-3.502
D(EC)	0.0096***	6.839	0.009***	7.466
D(LGDP)	-1.331***	-5.018	-3.087***	-4.552
D(TR)	0.002*	1.750	0.004***	3.180
D(POP)	0.071*	1.83	0.139***	4.587
D(LINV)	0.470***	4.330	**1.026*** **	5.479
Constant	52.898***	4.121	**F-statistic:** **Prob. (F-statistic)):**	22.60014 (0.000)

R-squared	0.96	0.96	**Adjusted R-squared**	0.916
ECM	-0.88	-0.88	**Durbin-Watson stat**	1.915

The short-term and long-term relationships between the independent variables (FDI, GDP, EC, TR, and POP) and the dependent variable (CO2) are shown in Table 4 and are explained below.

$CO2 = \beta\mathbf{0} + \beta\mathbf{1}GDP + \beta\mathbf{2}FDI + \beta\mathbf{3}EC + \beta\mathbf{4}\ \mathbf{TR} + \beta\mathbf{5}\ \mathbf{INV} + \beta\mathbf{6}\ \mathbf{POP} + \varepsilon_t$

The findings demonstrate that 'FDI has a long-term and short-term negative and statistically significant impact on CO2 emissions. This implies that higher FDI inflows help reduce environmental degradation in Pakistan. A possible reason is that 'foreign investment may introduce modern technology and more efficient production methods that generate fewer emissions. This finding agrees with Tasri & Karimi (2019) but differs from Solarin et al. (2017), Sun et al. (2017), and Qureshi (2006), who found evidence supporting the PPH. Furthermore, EC has a positive and significant effect on CO_2 emissions in both the short run and the long run. This indicates that greater energy use increases CO2. Since Pakistan relies mainly on fossil fuels, higher energy demand leads to higher environmental pollution. This result is consistent with Halicioglu (2009), Hossain (2011), and Shahbaz et al. (2012). However, GDP has a negative and significant relationship with CO_2 emissions in both the short run and the long run. The results suggest that EG is associated with lower CO2, possibly because of improvements in technology, better energy efficiency, and increased environmental awareness. This finding supports the EKC hypothesis and is consistent with Bilgili et al. (2012) and Babalwa and Andrew (2017).

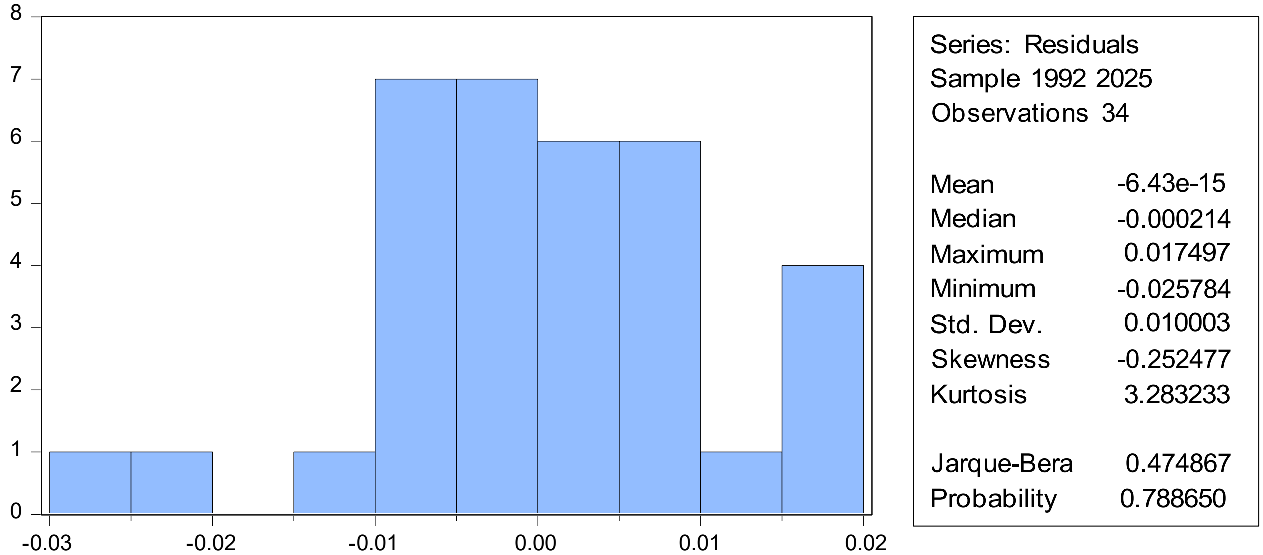
Trade openness has a positive and significant impact on CO_2 emissions in both the short run and the long run. This suggests that increased trade activities are associated with higher industrial production, transportation, and energy use, which increase CO2. This finding is in line with Halicioglu (2009) and Shahzad et al. (2017), although it differs from Shahbaz et al. (2012), who reported that trade openness could reduce emissions through technology transfer. Moreover, population growth also has a positive and significant effect on CO_2 emissions in both the short run and the long run. This indicates that population growth raises the demand for energy and other resources, resulting in higher CO2 emissions. This finding is consistent with Ahmed et al. (2016). Furthermore, investment, measured in logarithmic form, has a positive and statistically significant effect on CO_2 emissions in both the short run and the long run. This suggests that increased investment is linked with greater industrial and infrastructure activities, which raise EC and CO2. This result is consistent with Tasri & Karimi (2019).

Overall, the findings indicate that FDI and EG help reduce CO_2 emissions, while EC trade openness, population growth, and investment increase environmental degradation in Pakistan.

The model will converge to equilibrium from disequilibrium at a rate of 88% if the ECM value (-0.88) is negative and substantial'. There is 'no autocorrelation ', according to the Durbin-Watson value'. The 'F-statistic', which is 22.60014 and Prob, is positive. ('F-statistic') shows how well the model fits the data, and its value of 0.0000 indicates that the model as a whole is significant at 1% and the outcomes are trustworthy.

4.5 DIAGNOSTICS CHECKING

a) Normality test



'Diagnostic test examines the serial correlation, normality, stationarity and Heteroskedasticity in the model'.

The residuals are normally distributed, according to the Jarque-Bera normality test (JB = 0.474, p = 0.788). The null hypothesis of normality cannot be rejected because the probability value is higher than the 5% significance level, indicating that the residuals meet the normality assumption.

b) Serial Correlation:

	F-statistic	Prob. F(2,19)	Obs*R-squared	Prob. Chi-Square(2)
Breusch-Godfrey Serial Correlation LM Test:	0.015	0.901	0.036	0.849

The probability value (0.849) is higher than the 5% significance level, according to the 'Breusch-Godfrey LM' test. As a result, it is impossible to reject the null hypothesis that there is no serial correlation, indicating that there is no serial correlation in the estimated model.

c) Heteroskedasticity:

	F-statistic	Prob. F(17,16)	Obs*R-squared	Prob. Chi-Square(2)
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.817	0.658	15.805	0.537

The probability value (0.849) is higher than the 5% significance level, according to the Breusch-Godfrey LM test. As a result, it is impossible to reject the null hypothesis that there is no serial correlation, indicating that there is no serial correlation in the estimated model.

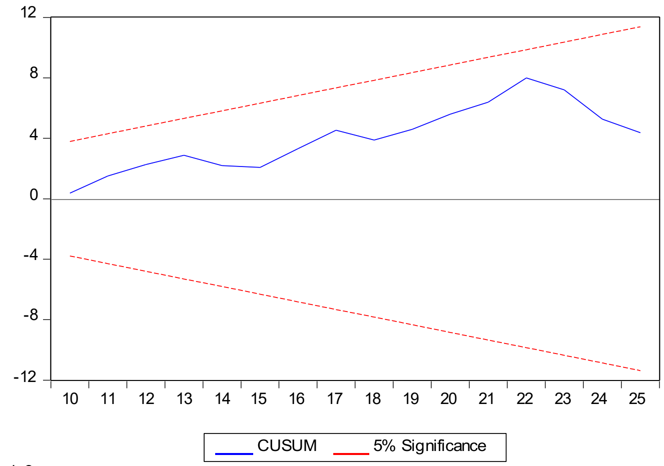
d) Ramsey RESET Test

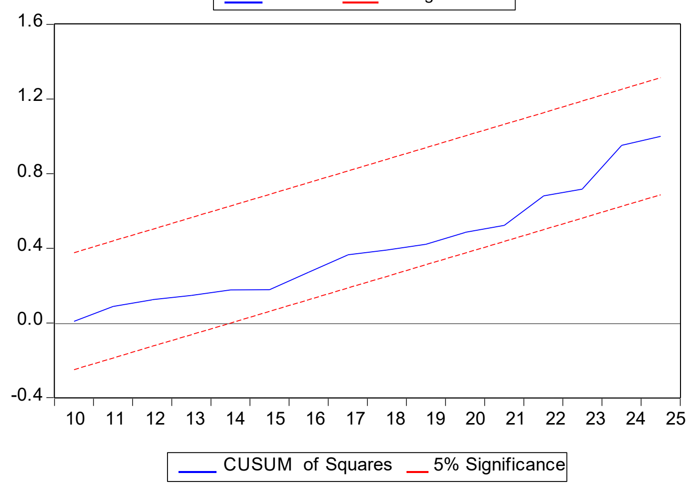
Ramsey RESET Test	**F-statistics**	**Prob.**	**F-statistics**	**Prob**
	0.1467	0.705	0.2830	0.7057

The 'Ramsey RESET' test reports an insignificant probability value (0.7057), indicating that the null hypothesis of correct model specification cannot be rejected. This finding confirms that the estimated model does not suffer from functional form misspecification.

e) CUSUM and CUSUM SQUARE:

CUSUM and CUSUMQ Stability Tests:





The 'Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests were used to assess the stability of the estimated ARDL model. The 'CUSUM and CUSUMSQ plots', as seen in the above figure, stay inside the 5% critical boundaries for the duration of the sample. So the computed coefficients are stable and have no structural instability because the null hypothesis of parameter stability cannot be rejected. The results confirm the robustness of the calculated ARDL model and the long term and short-term coefficient estimates.

5. CONCLUSIONS:

The primary objective of every country is to achieve economic growth because it increases the standard living of citizens, and it is an indicator of the country's overall economic performance. FDI is one of the key drivers of economic growth and growth is associated with employment creation, capital formation and knowledge transfer. The international investment could also have an adverse effect on the environmental quality of the host nation. There is a trade-off between luring FDI and preserving the environment in certain economies, but not in others. The PPH is endorsed if FDI increases environmental pollutants, particularly CO2 emissions.

However, the PPH Hypothesis is proved to be incorrect if the lowering of pollution is because of the adoption of green technology and manufacturing methods. The empirical results show that, in both the short and long term, FDI has a statistically significant negative impact on CO2 emissions. This means that FDI can also bring about better environmental quality, perhaps by bringing in greener and cleaner technology and the most modern and efficient production methods and management systems. As a result, in the case of Pakistan during the study period, the results do not support the PPH.

The findings also show that the energy use has a positive and significant effect on CO2 emissions, indicating the high level of dependence on fossil fuels in Pakistan which is a significant factor in environmental pollution. Likewise, trade openness and population growth and investment have positive and significant impacts on CO2 emissions, suggesting that increased trade and economic activity, industrial growth and increased energy demand all result in an increase in CO2 emissions. However, the negative correlation between the economic growth (GDP) and CO2 emissions is statistically significant, indicating that when the research period is considered, a positive economic growth was correlated with a negative CO2 emission.

The diagnostic tests confirmed the strength and statistical stability of the ARDL model. The results indicate that there are no serial correlation and heteroskedasticity, as the residuals are normally distributed. Moreover, the Ramsey RESET test and the CUSUM and the CUSUMSQ stability tests are also used to check the correctness of the model specification and the stability of the model structure.

This paper suggests a governmental environmental policy which will encourage foreign investors or multinational corporations (MNCs) to invest in green technology or positive environmental measures. Businesses that pollute more than the recommended amount and endanger the environment and public health may be subject to a particular carbon tax under the environmental regulation. Together with other academics, they have also suggested that countries that see a positive association between FDI and CO2 ought to impose taxes on multinational firms that cause pollution.

The findings of this study indicate that the government should consider, adopting policies and legislation that will make it attractive for foreign investors and multinational companies (MNCs) to invest in environmentally sustainable projects and green technologies. These regulations can encourage more environmentally friendly industrial methods while bolstering economic growth. The emission norms should be prescribed by environmental rules and a carbon tax or other environmental fines should be imposed on businesses which emit more CO_2 than is permitted. The actions would encourage companies to adopt more environmentally friendly technologies and reduce their pollution levels. As per the past research, the countries with positive correlation between FDI and CO_2 emission are advised to have more stringent environmental policies and implement carbon taxes for multinational firms with high pollution level to maintain the environmental quality.

6. RECOMMENDATIONS:

PPH analyses with the use of renewable sources of energy to lower pollution, not just CO_2, would probably lead to more progressive results. In the aggregate level of panel data analysis, other hazardous pollutants like methane, greenhouse gases and nitrous oxides can also be studied. Trade and FDI can have a good impact on employment, tax revenues, and economic return under certain conditions. Therefore, it is necessary that the manufacturing companies follow strict environmental rules with the use of the latest technology. They should also conduct awareness programs for energy conservation and environmentally sound production and consumption processes. Furthermore, raise funding for research and innovation and the development of clean technology for sustainable economic growth.

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Appendix

Table: A1

	CO2	EC	FDI	GDP	POP	TR	Inv
Obs	36	36	36	36	36	36	36
Mean	0.6222	101.873	1.62e+09	2.44e+11	2.279	30.494	3.49e+10
Std.Dev	0.049	13.414	1.32e+09	9.78e+10	0.595	4.656	9.98e+09
Minimum	0.496	75.719	2.45e+08	1.10e+11	1.302	21.459	2.05e+10
Maximum	0.702	117.861	5.59e+09	4.26e+11	3.343	38.489	5.50e+10