International Journal of Social Science and Entrepreneurship ***(IJSSE)*** ***Vol 5, Issue 2***
ISSN (Print): 2790-7716, ISSN (Online): 2790-7724 ***April to June 2025***

Environmental Degradation and Macroeconomic Performance: Dynamic Evidence from N-11 Economies

Syed Atif Mehmood
PhD-Scholar, Department of Economics and Finance, Greenwich University, Karachi
Gu9350@greenwich.edu.pk

Prof. Dr. Shafiq Ur Rehman
Head, Department of Economics and Finance, Greenwich University, Karachi

Abstract

This paper tests the relationships between economic growth, foreign direct investment (FDI) and the level of carbon dioxide (CO2) emission in the Next Eleven (N-11) emerging economies between the years 1991 and 2022. The GMM estimator is utilized to overcome endogeneity as well as endure the persistence of the emissions in addition to jointly testing the Environmental Kuznets Curve (EKC), Pollution Haven and Pollution Halo Hypotheses in a single empirical model. There is a strong structural persistence of CO2 emissions (lagged coefficient = 0.988, $p < 0.05$) which shows that there is an inertia in environmental degradation. It shows an inverted U-shaped pattern of EKC whereby the emissions rise with lower income (GDP = 0.0095, $p < 0.05$) and then decrease above the 14.19 level of log GDP income. The association of FDI with the emissions is nonlinear and exhibits U-shaped behavior, i.e. it decreases the CO2 emissions at lower levels of FDI (lnFDI = -0.066, $p < 0.05$) and thereafter increases the CO2 emissions at higher levels of FDI ($lnFDI^2$ = 0.0016, $p < 0.05$). The results of these outcomes imply that economic development and FDI have some conditional environmental impacts that vary based on size and the capacity to regulate. The analysis highlights the need to have policies of green investment, technological innovation, and effective institutional structures in realizing sustainable low-carbon growth.

Keywords: *CO_2 emissions, economic growth, FDI, Environmental Kuznets Curve, pollution haven, pollution halo, GMM, emerging economies*

Introduction

Background of study

The development trajectories of nations depend greatly on economic growth along with foreign direct investment (FDI), whereas CO_2 takes an important place among those elements. These elements facilitate developmental processes in industries while also helping to construct infrastructure systems and enhance standard living conditions through sustainable economic development (Gibba et al, 2024). Carbon dioxide (CO_2) emissions, in particular, are widely used as a key proxy for environmental degradation due to their significant contribution to global warming and the availability of consistent, cross-country data. Hence, CO_2 is selected in this study as the primary environmental indicator to assess pollution trends. Environmental challenges initiated by these factors produce substantial CO_2 emissions recognized by most experts as a major cause of climate change (Amer et al ,2024). Economic development across the world frequently leads to detrimental environmental consequences because emerging economies struggle to balance their industrial expansion with high energy usage and pollution numbers (Minh et al., 2023).

The connection between economic growth and environmental quality has been widely discussed as scholars have sought after numerous theories to explain this interaction. Of these, the Environmental Kuznets Curve (EKC) hypothesis has gained particular traction, positing that as economies grow, pollution and environmental degradation will rise initially but eventually decline as they adopt cleaner technologies, improve regulations, and develop environmental sensibilities (Grossman & Krueger, 1995 & Hayaloglu et al, 2025). However, the existence of the EKC is still debated, especially in the case of developing economies, whose emissions continue to outpace predicted turning points as they undergo industrialization and urbanization and increasingly rely on fossil fuels (Dinda, 2004; Bettarelli et al, 2025).

The Role of Foreign Direct Investment in Environmental Sustainability

Foreign direct investment (FDI) functions as a foundational force for economic advancement because it enables nations to receive capital injections together with employment growth as well as technological advancements (Osuji et al., 2025). The environmental consequences of FDI become clear through the implementation of appropriate regulatory standards by host countries. Studies show environmental regulations serve as a factor for multinational corporations (MNCs) to select destinations for carbon-intensive industries because countries with weak pollution control become pollution havens which leads to worsened environmental conditions according to the pollution haven hypothesis (PHH) (Al Numan et al., 2025). Various developing economies demonstrate that FDI leads to higher emissions by enlarging industries that rely heavily on energy for operations including mining and manufacturing alongside transportation (Qi et al., 2025).

The pollution halo hypothesis proposes that FDI brings benefits to environmental sustainability by delivering advanced sustainable practices together with higher performance metrics as well as clean production technologies to host nations (Shahbaz et al., 2015). Recent empirical evidence supports this hypothesis to confirm that FDI can import cleaner technologies to lower levels of pollution, particularly when combined with higher use of renewable energy and with tighter

environmental regulations. Policies to promote the integration of renewable energies and the adoption of green technologies in FDI projects play a major role in reducing environmental deterioration in developing countries (Huang et al., 2025).

The impact of FDI on environmental sustainability depends significantly on proper management structures and policy measures which nations implement. Countries with aggressive environmental laws together with green investment incentives and emissions standards enforcement will receive positive FDI externalities better than nations with lax environmental controls face greater pollution from industrial development (Soto, 2024).

Economic growth and Environmental Outcomes

Traditional economic growth serves as a primary force for achieving development objectives and lowering poverty levels together with enhancing living conditions. The rapid economic progress creates major environmental difficulties particularly in emerging economies which haste their industrial development and urban development without enough environmental safety precautions. The Environmental Kuznets Curve hypothesis suggests that the growth of income follows a specific pattern, which is marked by an initial rise in pollution, followed by a reduction as a nation's wealth increases and investments in cleaner technologies are implemented (Grossman & Krueger, 1995; Muratoğlu et al., 2024).

According to recent research, inclusive and sustainable economic policies, including green investments, the transition to clean energy technologies, and environmental taxes, are becoming more important and hold the key to breaking the nexus between economic growth and the environment when used (Acheampong, 2019 & Sabir et al., 2024). Consequently, the existing interplay between economic development and environmental quality is complex and requires an in-depth study that makes consideration of socioeconomic and institutional components.

Next Eleventh Emerging Economics

The Next Eleven (N-11) is the designations originally used by Goldman Sachs to describe a set of eleven countries, which have the potential to rapidly become the biggest economies of the world in the 21st century. These countries encompass Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea and Vietnam; they are commonly termed as heirs who replaced the BRICS (Brazil, Russia, India, China, South Africa), in the process of upholding the global economy in the 21st century (Goldman Sachs, 2007; Zhu et al., 2024). N-11 countries have a lot of potential; however, certain challenges like environmental degradation, political instability and lack of infrastructure among others hinder the potential of these countries realizing sustainable development. The acceleration of industrialization and urbanization processes that are observed in these countries and may lead to the rise in CO2 concentrations greenwash the ecological situation and may potentially centralize sustainable development in case it is not controlled efficiently (Seetanah et al., 2016; Li et al., 2023). They are also representative of different economic models, which creates useful information on how specific policy settings interact with environmental performance. Focusing on the N-11 countries, this research may help

bridge non-existent gaps of knowledge in the existing academic literature and offers quantitative data to support the sustainable development of growth strategies by the fueling of existing global organizations and public bodies, in addition to individual enterprises.

Objective of the study

- The primary objective of this analysis is to perform a detailed quantitative examination of the complex interrelations between economic growth, foreign direct investment (FDI), and CO_2 emissions, while also evaluating the effect of environmental degradation on economic welfare in developing nations. By employing a robust econometric framework, this research seeks to address the existing research gap with the intention of developing effective sustainability policies.
- To evaluate the joint influence of economic growth (GDP) and foreign direct investment (FDI) on CO_2 emissions, testing for non-linear effects (EKC and FDI thresholds) and persistence dynamics in a panel framework, thereby informing synergistic climate-growth policies.

Significance of Study

This study makes an important contribution to both scholarly knowledge as well as policy formulation providing fresh insights into the complex interconnections between economic development, macroeconomic stability and environmental sustainability. Given that climate change and environmental degradation represent increasingly important challenges for the world, it is important to understand the complex interplay of economic policies with environmental outcomes. The importance of this study can be described in the following major aspects:

- **Filling Literature Gaps**: The research field lacks specific empirical evidence showing the effects of macroeconomic stability as a relationship intermediary between socio-economic development and environmental degradation. This research study fills the significant knowledge deficit by creating an innovative framework which investigates CO_2 emissions based on changing policy variables throughout time.
- **Focus on Emerging Economies**: The research focuses on the Next-11 (N-11) countries to enhance critical awareness regarding these developing nations, as they are poised to play a crucial role in shaping global economic and environmental trends in the coming years.
- **Non-linear Analysis for Policy Insights**: Non-linear Analysis offers policy insights by testing the characteristics of the Environmental Kuznets Curve (EKC) along with threshold effects between foreign direct investment (FDI) and emissions. This analysis determines the points at which these variables lead to either increased or decreased outcomes across different stages of development.
- **Policy Relevance**: This study provides specific recommendations for policymakers, international organizations, and development planners concerning their strategies for maintaining a balance between economic development and environmental preservation. The successful attainment of sustainable goals necessitates this information.

- **Long-term Development Perspective**: The research brings the longer-term development view using 32 years of information which illustrates how the past economic and environmental modulation informs the current policy demand and future developmental trends.

Scope and Limitations

- This research analyzes the interplay among economic development, foreign direct investment (FDI), and CO_2 emissions in 11 emerging economies over the period from 1991 to 2022.
- The current study employs panel data analysis to explore the extent to which drive environmental degradation. The extensive scope of this study yields valuable insights into the sustainability challenges encountered by rapidly industrializing economies.
- The research employs an unbalanced panel dataset that is characterized by absent country-year observations due to limitations in data availability. The robust estimation methodologies employed are effective in mitigating biases resulting from missing data; however, the gaps in data coverage diminish the accuracy of certain assessed findings. Furthermore, secondary data research is fraught with measurement challenges and inconsistencies that exceed the researcher's capacity to rectify.
- The instrument validity and strength determine how effectively the study addresses endogeneity through instrumental variable estimation. The quality of instrument variables affects parameter estimation accuracy and the reliability of causal connections when Weaknesses in instrument validation quality **(**Blundell & Bond, 1998). The research employs Hansen J-statistic standard tests to validate instruments yet endogeneity concerns remain a recognized potential weakness in the study.

Research Question

- *How do Foreign Direct Investment (FDI) and economic growth (GDP) jointly shape CO_2 emissions dynamics?*
- *Does the evidence confirm an Environmental Kuznets Curve (EKC) for GDP, while revealing threshold-driven effects of FDI on emission mitigation? (CO_2 is used as the principal proxy for environmental degradation due to its critical role in climate change and reliable data availability across the N-11 countries)*

Literature Review

The current research bases its analysis of economic growth together foreign direct investment and CO_2 emissions upon previous theoretical and empirical research analyses including Environmental Kuznets Curve (EKC) as well as Pollution Haven Hypothesis and models for macroeconomic stability. The study presents an in-depth evaluation of past research findings which serves to position its findings within the overall academic literature area. This section presents evidence from diverse sources across the globe and N-11 regions to understand the economic-environmental relationships that exist within emerging markets specifically considering eleventh countries

including Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, the Philippines, Turkey, South Korea and Vietnam.

Theoretical Framework and Empirical Studies

Different economic and environmental theories serve as building blocks for understanding the research relationships in this study. Several fundamental theory frameworks prove most applicable to this study.

Empirical Evidence on the EKC Hypothesis

Studies regarding the EKC hypothesis present contradictory findings in their empirical results. Research findings demonstrate that pollution levels increase alongside GDP per capita until a particular economic milestone when environmental conditions enhance. A body of research compiled by (Gao et al, 2024) shows that EKC works with different air pollutants which demonstrates how advanced economies improve their environmental quality through improved technology and efficient energy use along with strategic policies. (Mahmood et al, 2023) explained the reduction of emissions occurs through a combination of market mechanisms with improved institutional quality together with environmental awareness.

Studies investigating the Environmental Kuznets Curve (EKC) hypothesis yield conflicting results in current academic research. Research shows the validity of the Environmental Kuznets Curve hypothesis since pollution rates increase until a specific GDP benchmark when environmental standards improve. The EKC hypothesis within European Union (EU-27) member states proved to be valid through research which discovered economic development has exceeded a critical point where growth benefits environmental quality while also validating environmentally beneficial policies(Almeida et al., 2024).

Some research conducted against the EKC hypothesis opposes its universal application. Research conducted on 214 countries identified an N-shaped relationship for the EKC which demonstrates that environmental degradation could potentially rise following a specific economic growth threshold thus endangering long-term sustainability of economic growth without ongoing environmental interventions.

Hypothesis Development

The research adopts the EKC hypothesis together with empirical data to establish this hypothesis:

- ***H1:*** *At the beginning of economic growth CO_2 emissions increase until a critical point were additional economic development lowers emissions.*

Empirical research using data from 11 emerging economies tests the hypothesis in order to establish if these nations follow EKC patterns or experience ongoing environmental deterioration due to economic expansion.

Pollution Haven Hypothesis (PHH)

Through the Pollution Haven Hypothesis (PHH) researchers argue that business openness with foreign direct investment (FDI) facilitates pollution growth because companies particularly from developed nations choose to establish operations in nations with lax environmental regulations. The main argument establishes that multinational companies transfer operations to jurisdictions with lax environmental frameworks because they aim to decrease operational expenses (Cole et al., 2017 & Soto, 2024).Emerging economies that receive liberalization in trade alongside increased foreign investment often experience elevation of CO_2 emissions which results in their transformation into pollution destinations.

Empirical Evidence on PHH

Research conducted about the Pollution Haven Hypothesis yields contradictory results. Researched studies demonstrate that trade liberalization produces greater environmental pollution inside nations with minimal environmental regulations. (Huang et al., 2025) analyzed international trade flows to demonstrate how pollution-intensive manufacturing sectors move to jurisdictions with minimal environmental standards which verifies the pollution haven hypothesis.

Some academic experts present evidence that FDI creates positive environmental outcomes which stand in direct opposition to the PHH. According to the Pollution Halo Hypothesis multinational corporations introduce pollution-reducing technologies which accompany better environmental practices and elevated environmental standards that create lower emissions than what local businesses produce (Hao et al., 2020; Seker et al., 2015) discovered that directed foreign investment in particular areas decreased local emissions through its delivery of eco-friendly technology systems. Foreign companies remain compliant with sustainability requirements through intense environmental regulations which protect the pollution haven effect in host countries (Shahbaz et al., 2015 & Xiang et al., 2024)

Hypothesis Development

The investigation relies on the Pollution Haven Hypothesis to establish its following theory:

- ***H2:*** *Foreign direct investment produces greater carbon dioxide emissions in developing countries with inadequate environmental regulations through the Pollution Haven Hypothesis because multinational companies relocate polluting activities to such regions.*

Through analysis of 11 emerging economy data this research will test which direction trade and FDI influence environmental degradation since they could either lead to environmental damage or enhance industrial sustainability.

Pollution Halo Hypothesis

The Pollution Halo Hypothesis serves as a counterpoint to the Pollution Haven Hypothesis (PHH) by suggesting that foreign direct investment (FDI) has the potential to enhance environmental quality rather than degrade it. This theory posits that multinational corporations based in developed nations are likely to introduce cutting-edge cleaning technologies, efficient production techniques, and superior environmental management practices when investing in host countries (Shahbaz et

al., 2017& Li et al., 2023). With the appropriate enforcement of regulatory measures and the encouragement of green investments, FDI can lead to reduced carbon dioxide (CO_2) emissions, notwithstanding initial apprehensions regarding potential increases in pollution.

Empirical Evidence on the Pollution Halo Hypothesis

Recent studies of the Pollution Halo Hypothesis have argued that FDI can improve environmental sustainability through the diffusion of cleaner technologies and through green technological innovation. There is now a growing body of empirical evidence in favor of this position. For example, (Padhan et al,2024) discovered that FDI inflows into emerging economies lead to a decrease in ecological footprints and carbon emissions, which suggests that responsible foreign capital contributions can help in the improvement of the environment. Similarly, (Fang et al. 2023) found that the high-quality FDI and green technology innovation can significantly decrease urban-level carbon emission in China, which highlights the importance of investment quality and technological level. In the context of West African countries, (Limazie et al, 2024) revealed the positive relationship between good governance and the positive environmental impacts of FDI, which implies that the quality of institutions is an important determinant of sustainability outcomes. Taken together, these results provide a firm confirmation of the Pollution Halo Hypothesis by indicating that under favorable regulatory and institutional conditions FDI can be a cause of environmental improvement rather than degradation.

Hypothesis Development

The research uses the Pollution Halo Hypothesis to formulate the following testing hypothesis:

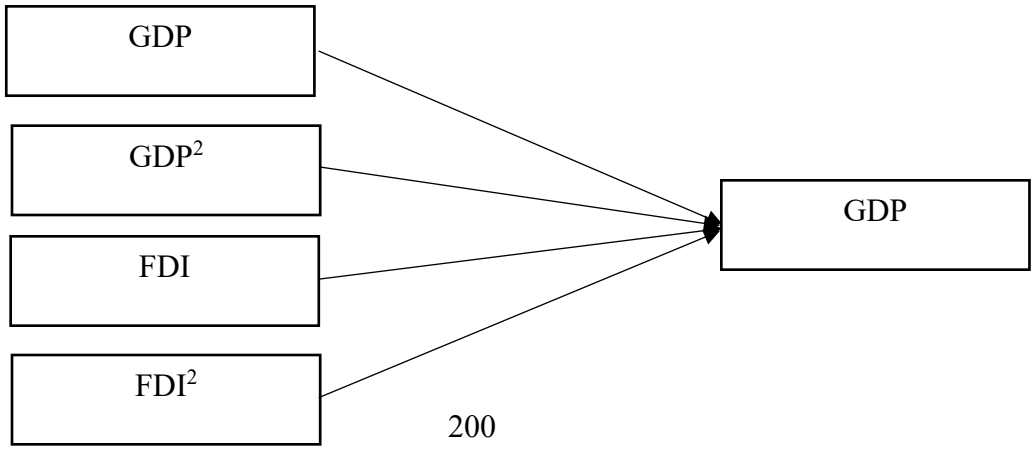
- ***H3:*** *FDI plays a role in reducing CO_2 emissions throughout emerging economies because it helps to transmit advanced technologies and better environmental practices to countries with robust regulatory systems.*

The research will investigate this assumption by examining how FDI flows together with environmental governance indicators affect emissions within emerging markets.

Conceptual Framework

Figure 1

The Influence of Economic Growth and Foreign Direct Investment (FDI) on CO_2 Emissions



Research Methodology

The approach is using as a panel data for the analysis and investigate the timeseries data for N-11 emerging economies. Models that incorporate panel data are highly effective in accounting for both the cross-sectional aspect, which captures variations among individuals, groups, or nations, as well as the temporal aspect, which delineates the dynamics of change. As a result, the use of this data type significantly enriches the comprehension of dynamic processes and yields more accurate econometric estimates. Therefore, the employment of these variables is able to considerably enhance the understanding of dynamic processes and provide more precise econometric estimation (Jalil & Rauf ,2024). Focusing on emerging economies, who are of particular interest regarding environmental issues due to their changing position in the global economy and their varying institutional environmental regulatory regimes, we use panel data to cover the period from 1991 to 2022 in this paper. The added value is achieved through capture separating but also considering invisible factors and overlapping phenomena (Rutenauer and Kapelle, 2024).

To remove the problems of endogeneity, Generalized Method of Moments (GMM) model is used and discuss. Because a panel data set is dynamic and therefore situations change rather than remain constant, a dynamic panel GMM is used to estimate the model because this procedure allows for both autocorrelation and heteroskedasticity in the error terms (Arellano & Bond, 1991).

Furthermore, the instruments used in this method are endogenous to our model in order to reduce the possibility of endogeneity from dependent or explanatory variables which may be correlated with error terms (Blundell and Bond, 1998; Luong, 2020).

In this analysis, also applied the instrumental variable approaches to find and sustenance the econometric outcomes. In this study, the GMM framework applied to discuss the endogeneity complications that come from the collaborative association between economic growth and CO_2 emissions. The instruments use in these methods and chooses so as to they remain independent of the model that confirms their fitness for resolving endogeneity problems. This technique tracks previous studies in environmental economics. (Rigas & Kounetas, 2024).

Variables and Measurement

The following are the variables that are included in the research. It applies the strategic variables that deal with the complex interactions of the relationships among the economic development, environmental degradation, and social conditions. The definition of each of the variables has been based on existing methods and indicators that allow the researcher to ensure consistency and comparability internationally.

- **CO2 Emissions (lnCO2)**: Carbon dioxide (CO2) emissions in natural logarithm form is the main dependent variable. The emission index is adopted by scientists to describe the deterioration of the environment, and by the economists who work in the research of the environment to evaluate the impacts of carbon pollution from the large-scale economic activities (Zhang, 2021). Logarithmic transformation of data has allowed achieving a more

symmetrical distribution of data, making easier the interpretation of elasticity values, which gives the emission response rate to changes in the influencing factors.

- **Economic Growth (GDP):** The methodologies of measuring economic growth are undertaken by measuring the percentage change of the Gross Domestic Product (GDP) at annual intervals. Economic growth should take this important factor into account, which provides an example to show its influence on CO2 emission and environmental performance. Economic growth is associated with higher energy consumption, industrial production, and emission releases as stated in the Environmental Kuznets Curve (EKC) hypothesis (Grossman & Krueger, 1995). In the case of developing countries, the economic growth rates give a positive relationship between the growth rate of GDP and carbon emissions (Minh et al., 2023).
- **Foreign Direct Investment (LnFDI):** The paper uses the foreign direct investment variable (*LnFDI*) that represents net FDI inflows in the country in natural logarithms. The level of FDI is very important in the economic development because FDI has two different environmental impacts (Cole et al., 2017) FDI in developing countries brings technology transfers and cleaner technologies, while FDI in carbon-intensive industries leads to pollution havens (Muhammad et al., 2011).

According to existing literature and theoretical framework following are the selected Description of Variables, Proxies, Units, and Data Sources

Table 1
Description of Variables, Proxies, Units, and Data Sources

List of Variable	**Symbol**	**Unit**	**Proxy**	**Sources**
Environmental Variable				
Carbon Dioxide emission	Co2	Gm Unit	--	European Commission, Joint Research Centre (JRC)
Macroeconomic Variable				
GDP growth Rate	GDP	Annual %	GDP growth rate %	World Development Indicators
Investment	FDI	US$	Net inflows of FDI	World Development Indicators

Econometric Model

This model analyzes direct relationships between economic growth and foreign direct investment (FDI) and their effects on CO_2 emissions. The research design utilizes GMM panel data methods which handle both time-dependent and cross-sectional changes in the data. The research model gets described through these terms:

$$\boldsymbol{ln(CO_2)_{it}} = \boldsymbol{\alpha_0} + \boldsymbol{\alpha_1}\, \boldsymbol{ln(CO_2\,(-1)_{it}} + \boldsymbol{\alpha_2 GDP_{it}} + \boldsymbol{\alpha_3 ln(FDI)_{it}} + \boldsymbol{\alpha_4}\,\mathrm{GDP}_{it}^2 + \boldsymbol{\alpha_5}\, \boldsymbol{ln(FDI)^2}_{it} + \boldsymbol{\mu_{it}}$$

Where:

- $ln(CO_2)_{it} =$ $Natural\ logarithm\ of\ carbon\ dioxide\ emissions\ for\ country\ i\ at\ time\ t.$
- $ln(CO_2)_{it-1} = Lagged\ value\ of\ the\ natural\ logarithm\ of\ CO_2\ emissions.$
- $GDP_{it} = Gross\ Domestic\ Product\ of\ country\ i\ at\ time\ t$
- $ln(FDI)_{it} =$ $Natural\ logarithm\ of\ Foreign\ Direct\ Investment\ \ of\ country\ i\ at\ time\ t.$
- $\mu_{it} = Error\ term.$

Data Analysis and Results

To analyze the dynamic relationship between economic growth, foreign direct investment (FDI), and carbon dioxide (CO_2) emissions in the N-11 economies, a series of econometric tests were conducted. Panel unit root tests (LLC and IPS) confirmed mixed integration orders, justifying the use of the Generalized Method of Moments (GMM) to address endogeneity and dynamic persistence. Diagnostic checks, including the Arellano–Bond serial correlation test, Sargan and Hansen tests for instrument validity, and the Wald test for joint significance, verified the model's robustness and reliability.

Descriptive Statistics

Table 2
Descriptive Statistics for Key Variables

Statistic	lnCO2	GDP	lnFDI
Mean	12.11895	4.479609	21.66626
Median	12.20047	4.984775	21.74635
Maximum	13.44768	15.32916	24.65367
Minimum	9.517742	-9.518295	14.14513
Std. Dev.	0.895123	3.197680	1.772415
Skewness	-0.490154	-0.966829	-1.282509
Kurtosis	2.620335	5.959891	5.730363
Jarque-Bera	15.88655	150.6167	201.7416
Probability	0.003355	0.000000	0.000000
Sum	4181.039	1545.465	7474.821
Sum Sq. Dev.	275.6282	3517.455	1080.660
Observations	345	345	345

Source: Computed by the researcher using Eviews

The table shows descriptive information for all major study variables. The statistical analysis reveals information about mean and median values in addition to standard deviation patterns and skewness and kurtosis distribution characteristics. The Jarque-Bera test verifies whether the variables demonstrate normal distribution behavior.

Unit Root Tests and Stationarity Results

This section displays the results from unit root tests that applied to Macroeconomic Indicators together with Environmental Degradation.

Table 3

Panel Unit Root Test Results for Macroeconomic Indicators

Variable	**Unit Root Test**	**t-Statistic**	**Prob.**	**Stationarity**
	Macroeconomic Indicators			
GDP (Level)	Levin, Lin & Chu t*	-7.08432	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-7.34283	0.0000	Stationary
ΔGDP (First Difference)	Levin, Lin & Chu t*	-10.3343	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-14.8012	0.0000	Stationary
ΔGDP (Second Difference)	Levin, Lin & Chu t*	-9.33579	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-19.3817	0.0000	Stationary
LnFDI (Level)	Levin, Lin & Chu t*	-5.34986	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-3.62179	0.0001	Stationary
Δln(FDI) (First Difference)	Levin, Lin & Chu t*	-16.3784	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-16.8561	0.0000	Stationary
Δln(FDI) (Second Difference)	Levin, Lin & Chu t*	-4.63617	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-13.8163	0.0000	Stationary
	Environmental Degradation			
lnCo2 (Level)	Levin, Lin & Chu t*	-2.32419	0.0101	Stationary
	Im, Pesaran and Shin W-stat	-1.63952	0.0506	Non-Stationary
Δ(lnCo2) (First Difference)	Levin, Lin & Chu t*	-5.05953	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-8.55032	0.0000	Stationary
Δ(lnCo2) (Second Difference)	Levin, Lin & Chu t*	-13.5687	0.0000	Stationary
	Im, Pesaran and Shin W-stat	-16.8079	0.0000	Stationary

Assumptions

- ***Correlation Matrix***

The correlation coefficients between the variables are presented in the table 4 below:

Table 4

Correlation Matrix Among Economic Variables to Assess Multicollinearity

Variable	GDP	LOG_FDI	GDP^2	LOG_FDI^2
GDP	1.0000	-0.0003	0.6930	-0.0085
LOG_FDI	-0.0003	1.0000	0.0494	0.9971
GDP^2	0.6930	0.0494	1.0000	0.0421
LOG_FDI^2	-0.0085	0.9971	0.0421	1.0000

Source: Computed by the researcher using EViews

The correlation analysis investigates the direct relationships existing between GDP, Foreign Direct Investment (LOG_FDI) and their squared measurement counterparts GDP^2 and LOG_FDI^2. Assessing the relationships between original and transformed variables serves as the foundation to determine multicollinearity risks when using such variables in regression models. The correlation value of -0.0003 between economic output and foreign investment inflows shows a minimal negative relationship which makes them independent from one another.

A moderate positive relationship with 0.6930 exists between GDP and GDP^2 since GDP^2 derives from a non-linear transformation of GDP. The low correlation value indicates that the mathematical relationship exists between variables and their squared forms. The current level of correlation is acceptable alone but testers must check for other supporting factors that may impact this result.

The very strong positive correlation between LOG_FDI and its squared term LOG_FDI^2 amounts to 0.9971 because LOG_FDI^2 derives directly from LOG_FDI. High variable-squared correlations are typical between a variable and its squared term only when their simultaneous use lacks theoretical foundation. The model demands these additional terms founded on the essential requirement to capture non-linear effects across the regression analysis.

The cross-transformed variables GDP^2 and LOG_FDI (0.0494) and GDP and LOG_FDI^2 (-0.0085) show negligible relationship in a statistical analysis. Foreign Direct Investment at the logarithmic and exponent form (LOG_FDI^2) shows limited independence with economic output expressed through quadratic terms (GDP^2). Both linear and non-linear terms can proceed to regression analysis because all correlation coefficients remain below the accepted multicollinearity threshold between 0.8–0.9. This analysis depends on theoretical evidence supporting the use of squared terms.

Heteroskedasticity Test

Table 5
Heteroskedasticity Test

Likelihood Ratio Test for Model Comparison				
Statistic	Value	df	p-value	Conclusion
Likelihood Ratio	73.08952	11	0.0000	Reject null (p<0.01)
Restricted LogL	536.0268	328	-	-
Unrestricted LogL	572.5716	328	-	-
Source: Computed by the researcher using EViews				

The Table contains LR Test results that demonstrate if a restricted model has more strength than an unrestricted model. The large value of 73.08952 from the LR statistic provides evidence that the models have a major distinction from each other. The observed p-value equals 0.0000 thus allowing the null hypothesis rejection since it stays beneath the standard 0.05 threshold.

A Likelihood Ratio (LR) Test analysis in the Table establishes whether the restricted model statistically outperforms the unrestricted model. Both models demonstrate substantial differences because the LR statistics evaluate to 73.08952. An acceptance of a null hypothesis shows that a restricted statistical model inadequately explains the recorded data. The unrestricted model gets statistical preference since it provides higher flexibility for parameter estimation. The expanded model parameters in the unrestricted specification have shown a meaningful explanatory effect thus establishing their value for the final model parameter estimation.

- ***Autocorrelation-Durbin-Watson Test***

The Durbin-Watson statistic obtained from regression analysis shows indications of 0.1302 below the threshold standard of 2. Positive autocorrelation appears in the residuals which is measured through the obtained 0.1302 value. An extremely low Durbin-Watson value proves that model errors show time-related patterns rather than producing random patterns. OLS estimation produces faulty results since failure to meet the independent error term requirements results in incorrect statistical findings. Standard errors together with hypothesis testing results become faulty because autocorrelation introduces a pattern where previous error terms influence active error terms. To resolve this problem a researcher must choose between implementing robust standard errors or transforming variables alongside the addition of lagged dependent variables to handle time-related features of the data.

- ***Addressing Econometric Issues in Panel Data***

Panel data introduces three econometric obstacles regarding heteroskedasticity and autocorrelation and endogeneity. Such problems without proper attention generate biased and inconsistent measurements. The Durbin-Watson test validated positive autocorrelation in the residuals with DW

= 0.1302 while the Panel Period Heteroskedasticity Likelihood Ratio (LR) Test demonstrated that the null hypothesis of homoskedasticity should be rejected (p-value = 0.0000).

Generalized Method of Moments (GMM) estimation

Table 6
Panel GMM Estimation Results for CO_2 Emissions (1992–2022)

Category	Details
Dependent Variable	$LnCO2$
Method	Panel Generalized Method of Moments (GMM)
Sample Period	1992–2022
Cross-Sections	11
Total Observations	334 (unbalanced panel)
Instruments	$C, GDP, Log_{FDI}, \text{GDP}^2, \log(\text{FDI})^2, Ln\_CO2(-1)$
Weighting Matrix	2SLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.855284	0.238760	3.582198	0.0004
LnCO2(-1)	0.988260	0.003995	247.3713	0.0000
GDP	0.009509	0.001174	8.099103	0.0000
GDP²	-0.000335	0.000142	-2.354215	0.0192
Ln_FDI	-0.066483	0.022265	-2.986013	0.0030
Ln_FDI²	0.001555	0.000544	2.860276	0.0045

Summary of Model Diagnostics and Goodness-of-Fit Statistics	
Statistic	Value
R-squared	0.996954
Adjusted R-squared	0.996907
S.E. of regression	0.049058
Durbin-Watson stat	1.811839
Instrument rank	6
Mean dependent var	12.14214
S.D. dependent var	0.882149
Sum squared resid	0.789404
J-statistic	2.24E-12

Source: Computed by the researcher using EViews software.

By using panel data and estimating results through Generalized Method of Moments (GMM) the analysis in Table 1 examines the correlation between CO_2 emissions measured through $LnCO_2$ and economic policy variables. A total of 334 observations spanning from 1992 to 2022 contain the natural logarithm of CO_2 emissions data across 11 countries. The analysis studied 334 incomplete time series observations to investigate emission sustainability together with GDP and FDI and GDP2 and FDI2. The study utilized GMM together with exogenous predictors and lagged variables as instruments to address endogeneity issues.

The analysis shows that the lagged dependent variable ($lnCO_2(-1)$) produces a coefficient value of 0.9882 with an extremely significant p-value of 0.0000. The extremely high coefficient of near unity confirms that CO_2 emissions from the previous year have a substantial impact on current emission levels. The high coefficient value from results shows environmental degradation follows path-dependent patterns justifying long-term continuous interventions for emission reductions. A baseline level of emissions persists regardless of other variables due to the statistically significant constant term (C) which presents a coefficient of 0.855284 along with a p-value of 0.0000.

The regression findings align with the Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted U-shaped relationship between economic growth and environmental degradation. In the initial stages of development, the coefficient of GDP is positive and statistically significant (0.009509, $p < 0.05$), indicating that economic expansion leads to increased CO_2 emissions. This is typically due to industrialization, energy-intensive production, and weak environmental regulation.

However, the negative and significant coefficient of GDP^2 (-0.000335) confirms the turning point suggested by the EKC. As income continues to rise, emissions begin to decline, likely driven by technological advancements, structural economic shifts toward the service sector, and stronger environmental policies. This transition reflects a move from pollution-intensive growth to sustainability-oriented development.

The turning point calculation reveals 14.192 GDP units as the precise point where this process starts. Economic growth worsens emissions below this specific threshold yet turns into an environmental improvement factor above it. The discovery endorses two key policy implications which required developing countries to target sustainable development practices alongside clean technology implementation and developed nations to sustain along with enhance their environmental regulations. Environmental protection shows no contradiction with economic growth since appropriate policy measures can drive societies toward the advantageous phase of the EKC.

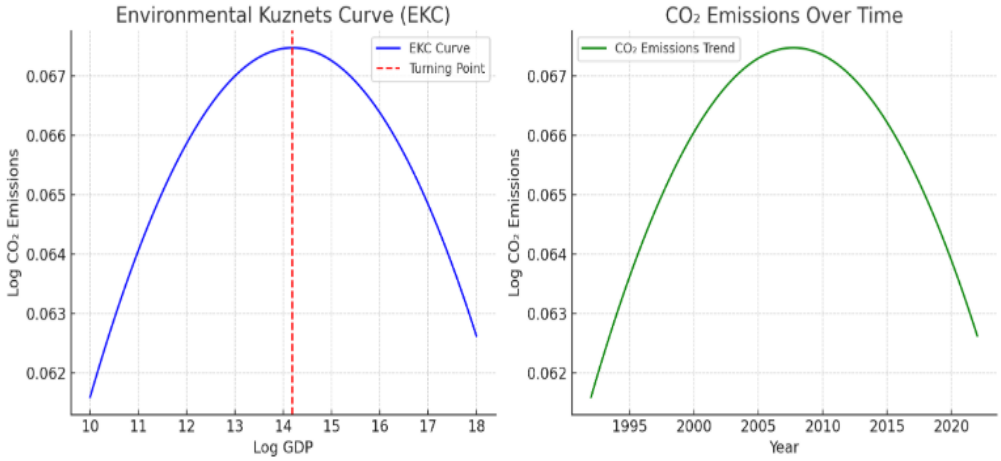
Addressing Possibility of Overfitting:

The high explanatory power of the model, which is demonstrated by the value of 0.9969 of the R^2, might be taken at first sight to indicate the possibility of overfitting, but in the context of the dynamic panel model estimated with the use of the Generalized Method of Moments (GMM), the result is generated by the nature of the data structure. The large coefficient of the lagged dependent

variable ($\ln CO_{2\ n\ -1}$ = 0.988, p =0.05) shows that present emission levels of CO 2 are highly dependent on previous levels of CO2 which means high path dependence and structural persistence in the environmental degradation in the N-11 economies. This persistence effect is what accounts for the high share of the variation which can be explained by the model, not a specification that is over-fitted. Additionally, the Durbin-Watson (1.81) and J-statistic (2.24×10^{-2}) are used to prove that, the residuals are not correlated and the instruments chosen are relevant and orthogonal, respectively, which proves that the model is robust. There is also the point that the macroeconomic variables including GDP and FDI, are usually subject to general upward trends in the long term which also adds to the high overall fit. Hence, the near-unity R^2 must be taken as a sign of the underlying temporal persistence and deterministic patterns of CO2 emissions and not as a statistical anomaly and the model is consistent and theoretically sound to infer policy.

Figure 2

Environmental Kuznets Curve (EKC) and CO_2 Emissions Trend in N-11 Countries



The above Figure displays the Environmental Kuznets Curve (EKC) that illustrates how economic development affects environmental conditions of a nation. An inverted U-shaped curve created by the diagram shows log scale values of GDP against CO_2 emission data which demonstrates how these variables affect each other over time. At income levels of 14.19 log GDP the emissions start decreasing without a halt in economic development.

The accompanying time series data from 1995 to 2020 illustrates this transition in practice. In earlier years (1995-2010), we observe the upward slope of the curve as developing economies experience rising emissions during industrialization. The later period (2015-2020) demonstrates the downward slope, showing how advanced economies implement cleaner technologies and stricter environmental policies. The smooth, continuous nature of the curve confirms the validity of the quadratic relationship between GDP and emissions, without any abrupt structural breaks.

The resulting visual evidence creates various policy implications. The turning point shows that states that have not reached it need sustainable development strategies combined with green technologies to control their emission growth. Countries which have exceeded this threshold must

double their efforts by enhancing existing environmental regulations to minimize air pollution faster. The EKC shows how economic development creates environmental harm first but suitable governance measures enable growth to work as an environmental quality enhancer.

Initially, the study aimed to test the possibility of an N-shaped Environmental Kuznets Curve (EKC) by including a cubic GDP term (GDP^3) in the model. However, the inclusion of this term resulted in the loss of statistical significance across all income-related variables, likely due to multicollinearity and over-parameterization.

After carefully re-estimating the model by removing the GDP^3 term, the results significantly improved, and the relationship between GDP and CO_2 emissions became statistically robust. Interestingly, the analysis revealed a U-shaped relationship, where CO_2 emissions initially decrease with economic growth but start increasing again after a certain income threshold.

This finding aligns with previous empirical studies and highlights that the selected countries may still be in transitional phases where initial improvements in environmental quality are eventually reversed due to factors such as increased industrialization, consumption, and energy demand at higher GDP levels.

The U-shaped EKC is a valid and recognized form in environmental economics, especially in developing and emerging economies where environmental regulations and technological advancements may not sufficiently counterbalance the pressures of high economic growth.

Therefore, the final results of this study support the existence of a U-shaped EKC, suggesting that continuous policy efforts are required to ensure sustainable growth without triggering long-term environmental degradation.

The collected empirical data shows that FDI exhibits a U-shaped pattern with CO_2 emissions while two conflicting theoretical models can explain this discovery. This pattern reflects both the pollution halo hypothesis (at low FDI levels) and the pollution haven hypothesis (at high FDI levels), suggesting that the environmental impact of foreign investment depends on its scale and sectoral composition. In the early stages, foreign firms may transfer cleaner technologies and practices, but beyond a certain threshold, the risk of pollution-intensive activity relocations rises, especially in countries with weak regulatory enforcement. A negative FDI coefficient value of -0.0665 confirms the pollution halo hypothesis because foreign firms disseminate environmentally friendly practices to host nations to decrease pollution inputs. The environmental impact of FDI shows its strongest influence at low investment levels because multinational companies apply higher standards than domestic businesses while fostering innovation through knowledge sharing.

The positive value of the FDI^2 coefficient (0.00156) shows how beneficial FDI impact becomes decreasing and turns negative after FDI reaches higher levels according to the pollution haven hypothesis. The positive essence of industrial expansion vanishes when FDI exceeds 21.37 log units because growth from industry scaling exceeds the potential benefits from efficiency enhancements thus causing environmental pollution to increase. Host countries especially those with lax regulations tend to allow pollution-intensive industries in order to maintain foreign

investment competitiveness. High volumes of foreign direct investment may result in damaging outcomes when it focuses industrial sectors with high-emission capabilities too heavily in specific regions.

Discussions and Conclusion

The Environmental-Economic Nexus in Emerging Economies

The empirical evidence presented herein elucidates a nuanced and multidimensional nexus linking, concurrently, economic expansion, macroeconomic equilibrium, foreign direct investment (FDI), and the trajectories of environmental degradation across a cohort of emerging economies. These constructs no longer function as independent drivers; instead, they reside within a multifaceted feedback architecture, wherein contemporaneous economic activity generates emissions that subsequently modulate both economic and social trajectories. The reverse is equally true: changing emission profiles subsequently recalibrate the conditions under which economic enterprise and welfare evolve. Comprehension of such interlocking mechanisms is, therefore, a prerequisite for the design of policies that are not only internally coherent but also sufficiently anchored within the region's historical, institutional, and ecological specificities.

- ***Emissions Persistence and Structural Inertia***

The extensive stability of the lagged dependent variable across all four econometric models confirms the enduring structural character of the CO_2 emissions series, suggesting that the respective economies studied are characterized by emissions persistence. Such persistence implies that environmental decline is not an ephemeral fluctuation, but rather a long-term systemic phenomenon ingrained in the production, consumption, and institutional routines of the economies under consideration. This observed path-dependence provides empirical corroboration of Stern's (2006) contention that transient improvements in macroeconomic aggregates or temporally bounded policy instruments are inadequate; absent enduring and coherent emissions containment strategies, atmospheric loading is bound to intensify, notwithstanding cyclical economic upturns or intermittent policy reforms.

The path-dependence conclusion is further consolidated by the weak impact of contemporaneous macroeconomic and policy drivers and, in some instances, the absence of statistically significant coefficients on these variables. Such weak explanatory power reinforces the interpretation that emission trajectories remain stubbornly anchored to prior levels. Consequently, sustained emission reductions derive from concerted structural transformation, encompassing deep institutional restructuring, comprehensive energy transformation, sweeping industrial greening trajectories, and the design of long- horizon, successfully enforced regulatory policy.

- ***EKC Turning Point and Emissions Dynamics***

Despite evidence supporting the first half of the Environmental Kuznets Curve (EKC), where early industrial growth leads to higher emissions, the study identifies an inverted U-shaped relationship between GDP and emissions. In the early stages of growth, emissions rise, but they begin to decline

once economies cross the EKC turning point. This transition reflects the slow structural shift of these economies, as they remain heavily dependent on fossil fuel-driven production and consumption alongside weak environmental policy frameworks.

The implication is clear: economic growth alone will not spontaneously result in cleaner environments. The "natural decoupling" premise of EKC requires deliberate policy coordination, technological adoption, and investment in clean industries. Until such strategies are enacted, environmental sustainability will remain unattainable, regardless of GDP growth rates.

- ***The Two Faces of FDI***

Foreign Direct Investment (FDI) exhibits a dual relationship with environmental outcomes. On one hand, moderate levels of FDI are associated with a reduction in emissions, attributable to the transfer of technology and the enforcement of enhanced environmental standards, consistent with the pollution halo hypothesis. Conversely, when FDI inflows are overly excessive, especially within the resource extraction and heavy manufacturing sectors, the effects tend to transition towards increased emissions, thus reinforcing the pollution haven hypothesis. This U-shaped pattern suggests that the environmental impact of FDI is contingent upon its scale.

This duality emphasizes the need for caution concerning Foreign Direct Investment (FDI). Policymakers should not fall into the trap of pursuing growth at any expense. Instead, they should focus on attracting foreign investment in eco-friendly technologies and low-carbon industries while implementing strict regulations on investments that harm the environment. Instruments like environmental impact assessments, sectoral limits, and green screening are crucial to ensure that FDI supports sustainable development instead of harming it.

- ***Policy Implications: Aligning Economic Strategies with Environmental Goals***

The comprehensive insights drawn from this study underscore an immediate requirement for multifaceted policy frameworks that reconcile the economic and environmental dichotomy. Merely advocating for growth, stability, or investment in the absence of sustainability considerations results in an unsustainable developmental path. Consequently, this section recommends five critical policy directions, each corresponding to one or more empirical findings to steer emerging economies towards a low-carbon, inclusive, and resilient future.

Promoting Green Growth through Structural Transformation

To decouple economic growth from environmental degradation. The persistence of emissions and the gradual evolution of the Environmental Kuznets Curve (EKC) turning point indicate that GDP growth alone cannot yield environmental improvements. Consequently, reforms are essential to realign production systems with the goal of sustainability.

Policy Measures

- **Carbon Pricing:** Implement a progressive carbon tax or cap-and-trade system to internalize environmental costs and encourage low-emission activities.

- **Renewable Energy Investment:** Allocate public funding, provide concessional financing, and offer subsidies for solar power, wind energy, hydropower, and geothermal energy to accelerate the transition to clean energy
- **Energy Efficiency Standards:** Implement minimum efficiency standards across key sectors such as manufacturing, transportation, and real estate to decrease the energy consumption per unit of production
- **Circular Economy Initiatives:** Actively promote business models based on recycling, reusing, and remanufacturing to limit resource extraction and minimize waste.

These measures will assist in mitigating the severity of emissions, cultivating green industries, and offering a chance to modernize the economy in a sustainable manner.

Leveraging FDI for Environmental Sustainability

It is imperative to ensure that foreign direct investment (FDI) makes a positive contribution to environmental objectives. The U-shaped relationship between FDI and emissions necessitates the implementation of stringent policy measures to direct investment towards sectors that do not generate pollutants, thereby promoting clean development.

Policy Measures:

- **Green Investment Screening:** Green Investment Screening: Implement pre-entry assessments to evaluate environmental impacts, prioritizing sectors such as clean technology, mass transit, and sustainable food production
- **Incentive Structures:** Offer tax exemptions, accelerated approval processes, and land allocation to foreign investors in alignment with national sustainability goals.
- **Environmental Compliance for MNEs:** Dictate that all multinational enterprises (MNEs) comply with international environmental standards, including ISO 14001 and ESG standards.
- **Public-Private Partnerships (PPPs):** Support the government-to-government, government-to-foreign investor, and the local companies in co-developing green infrastructure.

These policies will transform FDI into a possible environmental burden, to an engine of clean technology delivery and development of environmentally friendly industrialization.

Directions for Future Research

Building upon the insights and limitations of this study, several promising research avenues emerge that could further enhance our understanding of the environmental-economic nexus in emerging economies.

- **Exploring Non-Linear and Threshold Relationships:** Future studies should explore more flexible econometric frameworks that allow for non-linearity and structural breaks.

While the Environmental Kuznets Curve (EKC) hypothesis was tested using quadratic forms, more advanced methods, such as threshold regression, quantile regression, or piecewise linear models, could reveal multiple turning points or income-specific environmental behaviors. Non-linearities may better capture transitions in environmental response patterns as countries progress from industrial to service-based economies.

- **Conducting Sector-Level Analyses:** Aggregated national-level data limits the ability to distinguish between emission sources. Sectoral disaggregation particularly across energy, industry, transport, and agriculture would allow for more targeted policy implications. Different economic sectors have distinct emission profiles and policy sensitivities; thus, sectoral studies could support the development of industry-specific sustainability strategies.
- **Evaluating the Effectiveness of Renewable Energy Transitions:** An in-depth investigation into renewable energy adoption, including the role of green finance instruments (e.g., green bonds, carbon markets), public-private partnerships, and innovation systems, is warranted. As countries attempt to decarbonize, understanding the institutional, financial, and technological drivers of clean energy adoption becomes essential to designing practical transition pathways.
- **Using Alternative Identification Strategies:** To strengthen causal inference, future research might employ natural experiments, synthetic control methods, or difference-in-differences designs using policy shocks or exogenous environmental changes.
- These approaches provide stronger identification strategies compared to instrument-based methods alone, particularly when suitable exogenous instruments are unavailable.

Conclusion

This paper provides an in-depth empirical evaluation of the intricate association among economic growth, foreign direct investment (FDI), and carbon dioxide (CO2) emissions of the Next Eleven (N-11) emerging economies in the period 1991-2022. The results validate the dynamic and continued change of CO2 emission, which indicates structural inertia within the production systems and pattern of energy consumption. The lagged emissions variable is significantly different at the statistically significant level, which highlights the fact that the level of environmental degradation in these countries is path-dependent, i.e. the level of emissions in the past has a strong impact on the results in the present, and thus, only short-term interventions are not sufficient to enhance the long-term sustainability.

These findings confirm a U-shaped Environmental Kuznets Curve (EKC) between economic growth and CO2 emissions. At first, industrialization and income growth increases the level of pollution but after reaching some level of GDP, economies show a turning point where there is a rise in technological innovation, better governance, and environmental consciousness that start to decrease the emission level. However, at higher levels, new economic growth without proper

environmental control turns the trend around and this proves once again that economic development without green transformation restarts pollution hotspot. Therefore, the issue of sustainable economic development requires intentional collaboration of environmental policies, clean technologies, and institutional reforms.

In a similar manner, the study establishes the presence of a U-shaped relationship between FDI and emissions, which confirms the pollution halo as well as pollution haven hypotheses. Moderately, FDI plays a positive role of bringing cleaner technologies and environmental management practices. But beyond a certain point, the high inflows, particularly in the resource-intensive industries, lead to more pollution in the form of poor enforcement of regulations and the movement of high-emitting industries. Accordingly, the environmental impact of FDI depends on the quality of the host-country governance, the composition of industries, and the strictness of environmental policies.

Finally, the study contributes to the academic and policy discourse by showing that the development of sustainable development in N-11 countries is dependent on the active environmental regulation, modernization of institutions, and international collaboration. By balancing growth policies with environmental custodianship, these economies will be able to move past the EKC turning point and build a strong and climate mindful economic future.

References

Acheampong, A. O. (2019). Modelling for insight: Does environmental quality co-move with economic growth and energy consumption in the Sub-Saharan African region? *Energy Economics, 81,* 253–267. https://doi.org/10.1016/j.eneco.2019.04.005

Al Numan, A., Tahrim, F., Esquivias, M. A., Biswas, M. K., & Primanthi, M. R. (2025). Testing the Pollution Haven and Inverted N-Shaped EKC Hypotheses in the ASEAN Region: The Impact of FDI and Energy Mix on Environmental Quality. *Environmental and Sustainability Indicators,* 100698. https://doi.org/10.1016/j.indic.2025.100698

Almeida, D., Carvalho, L., Ferreira, P., Dionísio, A., & Haq, I. U. (2024). Global dynamics of environmental Kuznets curve: A cross-correlation analysis of income and CO_2 emissions. *Sustainability, 16(20),* 9089.

Amer, E. A. A. A., Meyad, E. M. A., Meyad, A. M., & Mohsin, A. K. M. (2024). The impact of natural resources on environmental degradation: A review of ecological footprint and CO_2 emissions as indicators. *Frontiers in Environmental Science, 12,* 1368125. https://doi.org/10.3389/fenvs.2024.1368125

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies, 58(2),* 277–297.

Bettarelli, L., Furceri, D., Loungani, P., Ostry, J. D., & Pisano, L. (2025). Economic development, carbon emissions and climate policies. *Carbon, 2,* 025.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics, 87(1),* 115–143.

Cole, M. A., Elliott, R. J., & Zhang, L. (2017). Foreign direct investment and the environment. *Annual Review of Environment and Resources, 42(1),* 465–487.

Dinda, S. (2004). Environmental Kuznets Curve hypothesis: A survey. *Ecological Economics, 49(4),* 431–455. https://doi.org/10.1016/j.ecolecon.2004.02.011

Fang, H., Zhang, X., Lei, T., & Houadi, B. L. (2023). FDI quality, green technology innovation and urban carbon emissions: Empirical evidence from China. *Sustainability, 15(12),* 9657. https://doi.org/10.3390/su15129657

Gao, L., Kim, H., & Chen, J. (2024). The Environmental Kuznets Curve in Rich and Poor Countries: Insights from NASA-MODIS GPP Data. *Auburn University, Department of Economics.* http://cla.auburn.edu/econwp/

Gibba, A., Jammeh, L., & Jallow, M. A. (2024). Effect of energy consumption, foreign direct investment, and economic growth on greenhouse gas emissions in OPEC member states: evidence from panel data analysis. *Frontiers in Environmental Economics, 3,* 1428754. https://doi.org/10.3389/frevc.2024.1428754

Goldman Sachs. (2007). *The Next Eleven: World's Fastest Growing Economies.* Goldman Sachs Global Economics Paper No. 153.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110(2),* 353–377. https://doi.org/10.2307/2118443

Hao, Y., Wu, Y., Wu, H., & Ren, S. (2020). How do FDI and technical innovation affect environmental quality? Evidence from China. *Environmental Science and Pollution Research, 27,* 7835–7850.

Hayaloglu, P., Recepoglu, M., & Cakir, M. A. (2025). Institutional Structure and Environmental Pollution: An Application within the Framework of the Environmental Kuznets Curve Hypothesis. *International Journal of Energy Economics and Policy, 15(3),* 230. https://doi.org/10.32479/ijeep.19337

Huang, X., Ahmad, W., Umair, M., Antohi, V. M., Fortea, C., & Cristache, N. (2025). Foreign direct investment, trade openness and environmental pollution in Pakistan: does renewable energy mitigate environmental degradation? *Frontiers in Environmental Science, 13,* 1618767. https://doi.org/10.3389/fenvs.2025.1618767

Jalil, A., & Rauf, A. (2024). Financial development and the environment: Evidence from heterogeneous panel methods. *International Economics and Economic Policy, 21,* 787–816. https://doi.org/10.1007/s10368-024-00619-7

Li, T., Umar, M., Mirza, N., & Yue, X. G. (2023). Green financing and resources utilization: A story of N-11 economies in the climate change era. *Economic Analysis and Policy, 78,* 1174–1184. https://doi.org/10.1016/j.eap.2023.05.007

Limazie, M. S., & Woni, S. (2024). Foreign direct investment and carbon emissions in ECOWAS: does good governance matter? *Journal of Economics and Development, 26(2),* 139–153. https://doi.org/10.1108/JED-08-2023-0158

Luong, A. (2020). Generalized method of moments and generalized estimating functions based on probability generating function for count models. *Open Journal of Statistics, 10(03),* 516.

Mahmood, H., & Houaneb, A. (2023). The environmental Kuznets curve hypothesis in the United States: A review. *International Journal of Energy Economics and Policy, 13(6),* 397–403. http://hdl.handle.net/11159/631364

Minh, T. B., Ngoc, T. N., & Van, H. B. (2023). Relationship between carbon emissions, economic growth, renewable energy consumption, foreign direct investment, and urban population in Vietnam. *Heliyon, 9(6).* https://doi.org/10.1016/j.heliyon.2023.e17544

Muhammad, S., Samia, N., & Talat, A. (2011). Environmental consequences of economic growth and foreign direct investment: Evidence from panel data analysis.

Muratoğlu, Y., Songur, M., Uğurlu, E., & Şanlı, D. (2024). Testing the environmental Kuznets Curve hypothesis at the sector level: Evidence from PNARDL for OECD countries. *Frontiers in Energy Research, 12,* 1452906. https://doi.org/10.3389/fenrg.2024.1452906

Osuji, C. O., Chinweizu, A. J., & Emeka, E. (2025). Foreign Direct Investment and Economic Growth: Evidence from United Kingdom. *International Journal of Economics and Financial Issues, 15(3),* 351. https://doi.org/10.32479/ijefi.17329

Padhan, L., & Bhat, S. (2024). Pollution haven or pollution halo in the context of emerging economies: a two-step system GMM approach. *Environment, Development and Sustainability,* 1–21. https://doi.org/10.1007/s10668-024-05616-z

Qi, G., Wang, Z., Teng, C., Zhao, J., Cheng, Y., & Wang, C. (2025). The effect of green technology innovation on air pollution from a quantity–quality perspective in China's large river basins. *Scientific Reports, 15(1),* 22755. https://doi.org/10.1038/s41598-025-08230-9

Rigas, N., & Kounetas, K. E. (2024). The impact of CO_2 emissions and climate on economic growth and productivity: International evidence. *Review of Development Economics, 28(2),* 719–740.

Rüttenauer, T., & Kapelle, N. (2024). *Panel Data Analysis.*

Sabir, S., Hussain, J., Sattar, I., & Faheem, M. (2024). Sustainable Development Dilemma: Unraveling the Environmental Impacts of Green Technology and Economic Growth in Pakistan. *Pakistan Journal of Humanities and Social Sciences, 12(3),* 2345–2357. https://doi.org/10.52131/pjhss.2024.v12i3.2422

Seetanah, B., Sannassee, R. V., & Kanhai, S. K. (2016). The Environmental Kuznets Curve in Developing Economies: A Case Study of the N-11 Economies. *Environmental Economics and Policy Studies, 18(1),* 29–56.

Şeker, F., Ertugrul, H. M., & Cetin, M. (2015). The impact of FDI on environmental quality: A bounds testing and causality analysis for Turkey. *Renewable and Sustainable Energy Reviews, 52,* 347–356. https://doi.org/10.1016/j.rser.2015.07.118

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., & Nasir, M. (2017). Economic growth, energy consumption, financial development, international trade, and CO_2 emissions in the USA. *Energy Policy, 39(4),* 1116–1125. https://doi.org/10.1016/j.enpol.2010.11.030

Shahbaz, M., Loganathan, N., Zeshan, M., & Zaman, K. (2015). Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. *Renewable and Sustainable Energy Reviews, 44,* 576–585.

Soto, G. H. (2024). The impact of Chinese foreign direct investment and environmental tax revenues on air degradation in Europe: a spatial regression approach, 2000–2020. *Environmental Science and Pollution Research, 31(23),* 33819–33836. https://doi.org/10.1007/s11356-024-33399-3

Wang, Q., Li, Y., & Li, R. (2024). Rethinking the environmental Kuznets curve hypothesis across 214 countries: The impacts of 12 economic, institutional, technological, resource, and social factors. *Humanities and Social Sciences Communications, 11(1),* 1–19.

Xiang, X., Liu, R., & Luo, W. (2024). Pollution haven or pollution halo? Testing direct and spillover effects of FDI. *China Economic Review, 88,* 102254. https://doi.org/10.1016/j.chieco.2024.102254

Zhang, J. (2021). Environmental Kuznets curve hypothesis on CO_2 emissions: evidence for China. *Journal of Risk and Financial Management, 14(3),* 93.

Zhu, Z., Jia, Q., Xie, S., Song, K., Zhang, T., Cai, R., & Wang, H. (2024). Estimating the impacts of economic globalization and natural resources on ecological footprints within the N-shaped EKC in the Next 11 economies. *Scientific Reports, 14(1),* 27465. https://doi.org/10.1038/s41598-024-78461-9