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Effect of Foreign Direct Investment, on Environmental Quality: A Case Study of Developing Economies

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Abstract

This study investigates the relationships between foreign direct investment (FDI), and environmental quality proxied by CO_2 emissions, in developing economies. This study uses data from the World Development Indicators (WDI) for 90 developing economies, covering the period from 1973 to 2022. Using panel quantile regression, the results show that FDI significantly impacts CO_2 emissions, supporting the pollution haven theory. Financial development measured by bank credit to the private sector, is also positively linked with CO_2 emissions. However, with a potential reversal when credit is channeled toward green initiatives. Renewable energy (RE) has a significantly negative impact on CO_2 emissions. Human capital (HC) significantly impacts CO_2 emissions because it is driven by increased economic activity, industrialization, and urbanization. These findings provide insights into the complex relationships between economic growth and environmental degradation. These findings highlight the need for policymakers to consider the environmental implications of FDI, FD, and HC, and to promote RE and green financing initiatives to mitigate CO_2 emissions in the developing economies.

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1. Introduction

Environmental pollution and its related challenges have become increasingly common in global discourse, gathering attention from policymakers, scholars, and stakeholders around the globe. The rise in greenhouse gas emissions (GHGs), specifically carbon dioxide (CO_2), has been a significant concern, with developing economies (Arshad and Parveen, 2024), particularly non-Annex I parties(developing economies), who play a vital part in this global trend (Hassan et al., 2022). In the light of the United Nations Framework Convention on Climate Change (UNFCC),the non-Annex I parties are primarily developing economies, including low-income and middle-income nations, as well as emerging economies. These economies are not subject to the same strict obligations for emissions reduction as Annex I countries under the Kyoto Protocol (1997). However, they are encouraged to take action toward climate change alleviation and adaptation, with support from developed countries (Abbasi et al., 2024).In developing economies, the interaction between FDI, FD, and economic growth significantly impact environmental quality. As explored by many studies for isntance (Hassan et al., 2022; Minh et al., 2023; Wijethunga et al., 2025), the surge in greenhouse gas emissions, pushed notably by the non-Annex I party, emphasizes the challenges facing developing economies. Despite global initiatives like the Paris Agreement 2015, these countries struggle with the quandary of organizing short-term economic gains facilitated by FDI, over long-term environmental sustainability (He et al., 2025). The Environmental Kuznets Curve (EKC) hypothesis acts as a theoretical model, indicating an inverted U-shaped association between economic growth and environmental deterioration (; Lau et al., 2025).

Kim and Seok (2023) state the relationship between FDI and environmental quality and test hypotheses like the pollution haven and pollution halo effects. Maroufi and Hajilary (2022) underline the urgent need for countries, including developing ones, to handle climate change amid boomingCO_2 emissions. Their study sheds light on the connection between FDI, energy consumption, and growth which is critical for understanding environmental policy outcomes. Nie et al. (2022) unfold this discussion to countries along the Belt and Road Initiative (BRI), which features a crucial role regarding FDI in shaping environmental results. Boamah et al. (2023) share the difficulties surroundingCO_2 emissions in African countries, stressing the need to examine the relationship between FDI and environmental factors thoroughly. Sheraz et al. (2022) deliver an understanding of the broader backdrop of global warming and climate change, underlining the importance of policies addressing FDI, RE, globalization, and institutional quality. Their study deepens the importance of incorporating these elements in environmental policy frameworks to reduce carbon emissions effectively. Ali et al. (2023) draw attention to the issue of environmental pollution across developing economies, reinforcing the need to accommodate economic growth with environmental protection. Their examination of the role of globalization and RE consumption in economic growth and environmental pollution nexus contributes precious insights for developing economiesIn summary, the combination of FDI, FD, and economic growth presents intricate challenges and opportunities in developing economies for environmental quality.Furhter, the connection between EQ and FDI is essential to economic growth and development. In addition, the studies on the relationship between EQ and FDI are limited to developed economies (Sitthivanh and Srithilat, 2022; Qamruzzaman , 2023; Xaisongkham and Liu, 2024). This research paper attempts to fill this active gap in the literature. However, by integrating findings from various studies, this research focuses on deepening our understanding of the mechanism underlying this relationship and informing evidence-based policy interventions to promote sustainable development.

2. Literature Review

Understanding the intricate connection between FD, FDI, economic growth, and RE consumption on CO_2 emissions is critical for constructing productive policies that intend at achieving sustainable development goals. This literature review synthesizes results from various studies to highlight the complex relationship between these components and their implications for EQ and economic growth. Multiple studies have examined the impact of FDI regardingCO_2 emissions, discovering different findings around different regions and economic contexts. For instance, a study by Weimin et al. (2021) finds a positive relationship between FDI and CO_2 emissions, implying that FDI inflows contribute to environmental degradation. Nie et al. (2022) find that FDI in Belt and Road countries has a substantial impact on carbon emissions, with the degree of GDP per capita impacting the relationship. The findings indicate a complex interaction between FDI and environmental degradation. Similarly, the study by Alhassan et al. (2022) points out a bidirectional causal relationship between FD and economic growth, applying a unidirectional causal effect with FDI on CO_2 emissions. Tran et al. (2022) study examines the association between FDI and CO_2 emissions and finds that FDI increases CO_2 by 4.2%. while CO_2 emissions impact FDI by 27.3%.

However, the connection between FDI and environmental deterioration appears to vary predicate on the level of economic development of host countries. Arif et al. (2022) observe a negative impact of FDI on CO_2emissions in developed economies, attributed to the adoption of cleaner production technologies. Conversely in developing economies, FDI leads to a rise in CO_2 emissions, confirming the pollution haven hypothesis. Wang and Huang (2022) study suggests that an increase in GDP per capita and FDI leads to an increase in CO_2 emissions in the short run. It also concludes that per capita GDP and FDI do not have a significant impact on CO_2 emissions in the long run. RE consumption appear as a key factor in reducing environmental degradation affiliated with economic growth and industrialization. Boamah et al. (2023) underscore the significance of balancing economic growth with environmental sustainability, stressing the function of renewable energy in decreasing CO_2 emissions. Similarly, Kim and Seok (2023) conclude that there is a negative impact of non-renewable energy consumption on CO_2 emissions, endorsing for the adoption of renewable energy sources to manage environmental challenges.

Furthermore, the literature delivers insights into the function of FD and economic growth in forming results for the environment. Ali et al. (2023) derive that the economic growth fosters pollution, while in the long run and short run renewable energy alleviates pollution. A bidirectional causal nexus between environmental pollution and economic growth, denoting interdependence. Boukhelkhal (2022) discovers a positive association between growth and CO_2 emissions, emphasizing the challenges that Africa faces in balancing economic development with environmental sustainability. On the contrary, Lv and Li (2021) identify an important negative spatial spillover effect of FD on CO_2 emissions, implying that stronger financial systems are connected with better environmental quality. Also by accelerating access to funds for environmental protection projects, and assisting investments in renewable energy and pollution control technologies (Khan and Ozturk, 2021; Sheraz et al., 2022).

Furthermore, to examine the direct influence of economic variables on CO_2emissions, multiple studies investigate the fundamental process driving these relationships. Khan et al. (2022) explore the long-run relationship between FDI, energy consumption, economic growth, and CO_2 emissions in the South Asian countries, revealing an Environmental Kuznets Curve (EKC) in form of a U-shape connection between income and CO_2 emissions. Hassan et al. (2022) finds in their results the existence of EKC hypothesis for Bangladesh, indicating that a possible shift from the carbon-intensive manufacturing to service industry. Maroufi and Hajilary (2022) imply that reducing non-renewable energy intensity expanding the share of renewable energy and are recognized as an efficient way to mitigate carbon emissions. The EKC hypothesis suggest a non-linear relationship between environmental deterioration and economic growth as it increases more primarily, as economic growth accelerates, pollution levels may rise due to a rise in energy consumption and industrial activity (Alaganthiran and Anaba, 2022).

The credibility and form of the EKC can differ depending on several factors, including the type of pollutants under study. Air and water pollution may observe various EKC patterns (Anwar et al.,2022) with the composition of economic activity. Economies that are swayed by pollutionintensive industries may display a steeper initial rise in pollution in comparison to those with a larger service sector (Minh et al., 2023). Similarly, Habiba and Xinbang (2022) discover that FD and RE consumption substantially reduce CO_2 emissions, stressing the significance of policy interventions directed at encouraging sustainable energy practices. The host country's absorptive capacity, and its aptitude to embrace and adapt new technologies, decide the strength of FDI in facilitating environmental improvements (Shah et al., 2022). The research from Khan et al. (2022) in the selected South Asian countries upholds the presence of the EKC hypothesis, implying that economic growth primarily leads to environmental degradation, which follows an improvement as income levels rise further.

Overall, the literature review reinforce the intricate relationship between , FDI, REC, on CO_2 emissions. Anwar et al. (2022) concluded that economic growth and FD give rise to environmental degradation in the long run, while renewable energy consumption is related to a decrease in environmental degradation. While economic growth and FDI inflows may primarily worsen environmental degradation, policy interventions focusing on sustainable development practices and renewable energy embracement can help ease these harmful impacts. CO_2 emissions initially accelerate economic growth but at a reducing rate, confirming the EKC hypothesis. Economic growth increases investments in advanced technologies and strict environmental regulations, reducing CO_2 emissions (Shinwari et al., 2022). Decreasing non-renewable energy intensity boosts the share of renewable energy and is recognized as an effective way to mitigate carbon emissions. Furthermore, research is needed to examine these relationships' delicate dynamics, particularly for the developing economies, eventually informing evidence-based policy decisions for achieving environmental sustainability and economic prosperity. Despite the fact that many authors have investigated the economic impact of FDI and its environmental effect in developing countries remain questionable. However, illustration on the different perspectives of the 'Pollution Haven' and 'Pollution Halo-hypotheses', this study formulate the following major hypotheses to empirically investigate the environmental influence of FDI in developing economies.

H1: Higher inflows of FDI are linked with degradation in environmental quality in developing economies.

H2: Higher inflows of FDI improve environmental quality in developing economies by introducing cleaner technologies.

3. Research Methodology

Data and Variables

In this study we utilized annual panel data over the period of 1973 to 2022 for the 90 developing economies based on World Bank data set. On the one hand, the considerations of the sample countries mainly depend on the accessibility of the data. On the other hand, to circumvent measurement error, we exclude countries in the dataset with no data, particularly, on the outcome variable. In addition to that, we provide a list of sample countries in appendix (Table A1). Further, the primary sources of our data World Bank's World Development Indicators (WDI). A detailed list of variables, their descriptions and their sources is provided in the appendix (Table A2).

Empirical Framework

We investigate the relationship between environmental quality and FDI including the control variables. The baseline model is provided below in Equation (1) where environmental quality (EQ) is the outcome variable, X_{it} represent a list of control variables and ε_{it} is the error term.

$$EQ_{it} = \beta_t FDI_{it} + \beta_t X_{it} + \varepsilon_{it} \dots \qquad \text{i} = 1,2,\dots,\text{N};\ \text{t} = 1,2,\dots,\text{N}, \qquad (1)$$

More particularly, the empirical model to examine the effect of these independent variables on environmental quality is given in Equation (2):

$$EQ_{it} = \alpha_{it} + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 GDP_{it}^3 + \beta_4 FDI_{it} + \beta_5 DCP_{it} + \beta_6 HC_{it} + \beta_7 RE_{it} + \varepsilon_{it} \cdots \qquad (2)$$

EQ_{it}refers to an environmental quality variable measured as carbon emissions (CO_2). GDP_{it} is GDP per capita. Based on the existing literature for instance, Ganda (2020) we incorporate its non linear form such as its squared indicator is GDP_{it}^2, and its tripled measure is GDP_{it}^3. Further, FDI_{it} represents net foreign direct investment inflows as a percentage of GDP, and DCP_{it} represents domestic credit to banking sector proxied for financial development. HC_{it} stands for labor status (labor force participation rate age 15+), while RE_{it} shows the green energy investment variable. All these variables are based on economic theory and existing literature, for instance (Khan et al., 2024; Elmonshid et al., 2024; Alvarado et al., 2024).

Estimation Technique

We estimate our empirical models using pooled OLS, fixed effects, and random effects techniques. These techniques provide the understanding of the average relationship between the explained variable and other relevant covariates (Ben-Salha and Zmami, 2020). Further, these models provide important understanding into mean effects; they may not pass to capture potential variations across different points in the distribution of the dependent variable. Therefore, in order to capture the variation across the different points in the distribution we utilize panel quantile regression, which offers a more comprehensive examination by revealing how the effects of explanatory variables may vary across various quantiles (Liu et al., 2020 ; Wang & Yan, 2022). The panel quantile regression (QR) method, primarily suggested by (Koenker and Bassett, 1978). This approach stretches the classical least-squares technique by modeling conditional quantiles of the distribution, feeding a more complete understanding of the relationship between variables. Unlike ordinary least squares (OLS), QR does not assume normally distributed errors, offering a stronger and subtle analysis. QR estimates are resistant to the influence of outliers, heteroscedasticity, and extreme distributions of the dependent variable (Koenker and Hallock, 2001), thereby providing a more accurate representation of the dependent variable's response to changes in the independent variables (Ben-Salha and Zmami, 2020). The conditional quantile regression for the dependent variable (EQ) can be written as:

$$EQ_{it}\left(\tau|X_{i,t}\right) = {X_{it}}^{\tau}\beta_{\tau} + \varepsilon_{it} \ldots \qquad \text{t \& i} = 1,2,\ldots,\text{N}; \qquad (3)$$

EQ_{it} is the dependent variable, $0 < \tau < 1, Q_{EQ_i}\ (\tau|X_i)\ X_{it}$denotes the explanatory variables, β_{τ} represents the unknown coefficients, and ε_{it} is the error term. Further, i denotes the developing countries, and t indicates the year.

$$EQ_{it}^{q} = FDI_t\alpha_1^q + X_{it}\beta_1^q + \epsilon_{it}^q \quad q = 10, 20, 30, 40, 50, 60, 70, 80, and\ 90 \qquad (4)$$

where EQ_{it}^{q} denotes environmental quality, FDI represents net foreign direct investment inflows, X_{it} represents a set of control variables as provided in Equation (2). In addition to that, in Equation (4) q represent the different quantiles of EQ and finally, ϵ_{it}^qrepresents the error term.

4. Results and Discussions

Table 1 depicts the descriptive statistics of the variables utilized in the analysis. Our dependent variable environmental quality (CO2) has the lowest mean value 2.1387 and standard deviation is 2.8864. Similarly, foreign direct investment (FDI) has the mean of 3.4528 and a standard deviation of 6.179 with skewness (9.3996) with kurtosis (181.056). The green house gases (GHG) has the highest mean value of 125000 with a standard deviation of 292000. Further,the results indicate significant skewness in all variables, suggesting that their distributions deviate from symmetry and are instead asymmetrically shaped.

Table1: Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max	p1	p99	Skew.	Kurt.
CO2	2789	2.1387	2.8864	0.02	17.26	0.04	14.27	2.29	8.6858
GHG	2789	125000	292000	179.35	3440000	378.32	1350000	5.9382	51.4317
FDI	2897	3.4528	6.179	-17.29	161.82	-3.08	27.76	9.3996	181.056
DCP	2830	29.8611	27.3477	0	174.97	0.75	127.72	1.7254	6.3743
GDP	2946	3956.395	6724.247	50.88	82800	138.71	33400	4.8042	36.2949
RE	2810	46.5162	32.1376	0.01	98.34	0.04	96.57	0.032	1.554
HC	1452	60.9166	9.973	26.49	93	36.93	85.85	-0.2061	3.6525

The variables exhibit positive kurtosis coefficients, indicating that their distributions have heavier tails and are more prone to outliers.The result of the summary statistics given in Table 1 including the range, mean and quantile values indicate that the data deviates significantly from a normal distribution. In addition to that we depicts other normality diagnostics which include the, **Jarque–Bera (jb) test**, **Shapiro–Wilk(swilk) test**, and finally **Shapiro–Francia test**. The findings are provided in appendix TableA3. The diverse patterns revealed by the descriptive statistics and normality diagnostics justify the use of panel quantile regression in this study, as it can effectively capture the varying relationships between variables.

Table 2: Multi-collinearity Test

Variable	VIF	Tolerance Level
RE	1.67	0.601
GDP	1.61	0.622
DCP	1.54	0.648
HC	1.22	0.823
FDI	1.12	0.892

Multi-collinearity is a common issue in regression analysis, resulting in unstable estimates and unreliable p-values leading to incorrect conclusions (BabajideAtoyebi and Obilade, 2024). Following Owoyemi and Obilade (2024), we apply the multi-collinearity test namely variable inflation factor (VIF) and Tolerance level on the given series as provided in Table 2. We perform a VIF analysis on the key independent variables to assess their degree of correlation. The results presented in Table 2 encapsulate that all VIF values are well below the threshold of 5, with the largest value being 1.63, revealing no multi-collinearity issues in the model indicating that the independent variables are sufficiently independent. The small tolerance level (1/VIF) values, reflecting the tolerance factor, suggest normality. The Threshold of tolerance level is 3, with the maximum value of 0.958 and the minimum value of 0.615. Therefore, we can conclude that multi-collinearity is not a concern in this study.

Table 3: Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) CO2	1.0000						
(2) GHG	0.2030	1.0000					
(3) FDI	0.1573	-0.1704	1.0000				
(4) DCP	0.4409	0.1318	0.1865	1.0000			
(5) GDP	0.6279	0.0731	0.3166	0.5264	1.0000		
(6) RE	-0.6687	-0.1663	-0.2039	-0.4646	-0.4400	1.0000	
(7) HC	-0.1174	-0.0749	0.0312	-0.0044	0.0409	0.3450	1.0000

The correlation matrix reveals significant insights into the relationship of environmental and economic variables. A strong positive correlation (0.6279) exists between CO_2 emissions and GDP, indicating that economic growth heavily relies on energy consumption and industrial activity, often tied to fossil fuel usage. Conversely, renewable energy (RE) exhibits a strong negative correlation with CO_2 emissions (-0.6687), underscoring its effectiveness in reducing carbon output, a critical finding for policy aimed at mitigating climate change. The weak positive correlation between CO_2

and GHG emissions (0.2030) suggests that while related, GHG emissions stem from other significant factors beyond CO_2 alone. Additionally, DCP moderately correlates positively with CO_2 emissions (0.4409), likely reflecting an increase in industrial activity fueling financial growth. In terms of GHG, weak correlations are observed across variables, with the largest being a weak positive link to DCP (0.1318) and a slight negative relationship with renewable energy (-0.1663). FDI has a weak negative correlation with GHG (-0.1704), potentially indicating some shift toward cleaner energy technologies. FDI also has a modest positive correlation with GDP (0.3166), demonstrating its role in economic growth but weakly negatively correlates with renewable energy (-0.2039), potentially reflecting initial reliance on conventional energy investments.

The role of renewable energy extends beyond reducing emissions; its moderate positive correlation with HC (0.3450) indicates potential links between environmental education and cleaner technology adoption (Gnangoin et al., 2022). GDP and HC minimally positively correlate (0.0409), while RE moderately inversely correlates with GDP (-0.4400), reflecting industrial dependence on non-renewables. Notably, DCP and HC virtually do not correlate (-0.0044), indicating limited financial-driven improvements in human development. Collectively, these findings emphasize the need for balanced, sustainable development strategies that integrate financial and environmental priorities while fostering renewable energy adoption and human capital growth. These results highlight the need for balanced policies integrating economic growth, environmental conservation, and human capital development. Prioritizing renewable energy and aligning financial systems with sustainability goals are key to decoupling economic progress from environmental harm, emphasizing a holistic approach to sustainable development.

Table 4: Panel Unit Root Test

	CD test	IPS		Fisher	
Variable		Constant	Trend	Constant	Trend
CO2	98.16***	2.976	-3.242***	193.20	228.67**
GDP	298.93***	15.450	-3.309***	43.45	127.70
FDI	48.33***	-13.178***	-16.042***	663.06***	612.33***
DCP	93.62***	3.220	-5.054***	174.85	228.84**
RE	94.48***	2.830	-2.452***	194.58	151.99
HC	4.61***	0	0	460.66***	461.08***

Following Ganda (2024) we apply CD test, IPS, and Fisher panel unit root test as depicted in Table 4. In case of CD test, there is no cross-sectional independence in this time series because it is asserted by the alternative hypothesis. However, based on CD test we find that the alternative hypothesis is accepted which suggests that the variables in this empirical analysis are cross-sectionally dependent by rejecting the null hypothesis. Table 4 conclude that the variables exhibit no unit root (stationary) at a mostly 1% significant level.

Quantiles Regression Results

In Table 5 we provide the empirical findings based on pooled regression(column1), fixed effects(column2), random effects(column3) and also on panel quantile regression(columns4 to12). The pooled regression analysis shows that there is a positive association between FDI and environmental quality (CO_2) emissions. Further, pooled regression analysis also suggests that a positive association between GDP and CO_2 emission is positively significant. In addition, the association between FDI and CO_2 emission remains highly significant and positive across the three differenct estimations techniqure namely pooled regression, fixed effects, and random effects models as depicted in columns 1,2 and,3. . However, RE appears with a negative sign across pooled regression, fixed effects, and random effects models. DCP also show a positive and significant impact on CO_2 emission across the pooled regression, fixed effects, and random effects models. Moreover, GDP2 is negatively associated with CO_2 emission for the sample countries in pooled regression, fixed effects, and random effects models.Following the existing literature for instance, Ghosh et al. (2014), Rashid et al. (2024) before applying the quantile regression analysis, we estimated the model using pooled OLS, fixed effects, and random effects approaches. These above mentioned panel data techniques were employed to present a baseline understanding of the average association between the dependent variable and the key explanatory variables while controlling for other relevant covariates (Ben-Salha and Zmami, 2020; Imran and Rashid, 2023). While these models offer useful insights into mean effects, they may not pass to capture potential variations across different points in the distribution of the outcome variable (CO_2). Therefore, we applied panel quantile regression, which offers a more comprehensive examination by revealing how the effects of explanatory variables may vary across various quantiles (Ben-Salha and Zmami 2020; Liu et al., 2023) and thus offers a deeper understanding of the underlying relationships (Fitzenberger and Wilke, 2015; Wang & Yan, 2022).

Table 5 – Panel Quantile Regression

	(1) CO2	(2) CO2	(3) CO2	(4) CO2	(5) CO2	(6) CO2	(7) CO2	(8) CO2	(9) CO2	(10) CO2	(11) CO2	(12) CO2
	Pooled OLS	**Fixed Effects**	**Random Effects**	Q.10	Q.20	Q.30	Q.40	Q.50	Q.60	Q.70	Q.80	Q.90
GDP	0.0003***	0.0003***	0.0003***	0.0002***	0.0001***	.0002***	0.0001***	0.0002***	0.0003***	0.0003***	0.0007***	0.0011***
	(1.68×10^{5})	(1.66×10^{-5})	(1.68×10^{5})	(0.0000259)	(2.11×10^{-6})	(4.97×10^{-6})	(2.35×10^{-6})	(1.13×10^{5})	(5.16×10^{-6})	(2.44×10^{-7})	(2.27×10^{-6})	(1.35×10^{5})
GDP_2	-5.48×10^{-9}***	-5.68×10^{-9}***	-5.48×10^{-9}***	-3.19×10^{-9}**	2.61×10^{-9}***	-5.96×10^{-10}***	8.69×10^{-9}***	7.09×10^{-9}***	5.60×10^{-9}***	1.91×10^{-9}***	-1.49×10^{-8}***	-2.59×10^{-8}***
	(7.79×10^{-10})	(7.67×10^{-10})	(7.79×10^{-10})	(1.52×10^{-9})	(1.36×10^{-10})	(1.87×10^{-10})	(1.69×10^{-10})	(5.67×10^{-10})	(3.13×10^{-10})	(1.48×10^{-11})	(1.45×10^{-10})	(3.78×10^{-10})
GDP 3	2.49×10^{-14}**	2.76×10^{-14}***	2.49×10^{-14}***	2.35×10^{-14}	-5.46×10^{-14}***	-2.93×10^{-14}***	-1.54×10^{-13}***	-1.44×10^{-13}***	-1.48×10^{-13}***	-9.65×10^{-14}***	8.11×10^{-14}***	1.77×10^{-13}***
	(9.33×10^{-15})	(9.18×10^{-15})	(9.33×10^{-15})	(1.76×10^{-14})	(1.80×10^{-15})	(1.94×10^{-15})	(2.32×10^{-15})	(7.16×10^{-15})	(3.71×10^{-15})	(2.15×10^{-16})	(2.00×10^{-15})	(3.56×10^{-15})
FDI	1.58×10^{-11}***	1.47×10^{-11}***	1.58×10^{-11}***	0.0091**	0.0172***	0.0127***	0.0057***	0.006	0.018***	0.0112***	-0.0079***	-0.0177***
	(3.19×10^{-12})	(3.14×10^{-12})	(3.19×10^{-12})	(0.0045)	(0.0003)	(0.0004)	(0.0003)	(0.0038)	(0.0006)	(0.0001)	(0.0016)	(0.002)
DCP	0.0028*	0.0035**	0.0028*	0.0038***	0.003***	0.0012***	0.0041***	0.0042***	0.0067***	0.0033***	-0.0078***	-0.0157***
	(0.0016)	(0.0016)	(0.0016)	(0.0004)	(0.0001)	(0.0001)	(0.0001)	(0.0007)	(4.49×10^{5})	(1.54×10^{5})	(0.0004)	(0.0008)
RE	-0.0163***	-0.0073**	-0.0163***	-0.0148***	-0.0211***	-0.0216***	-0.0278***	-0.0241***	-0.0264***	-0.0321***	-0.0373***	-0.0389***
	(0.003)	(0.0033)	(0.003)	(0.0015)	(0.0003)	(0.0003)	(0.0001)	(0.0004)	(0.0001)	(0.002)	(0.0002)	(0.0026)
HC	-0.0002	0.0008	-0.0002	-0.0022***	-0.0031***	0.0017***	0.0019***	0.0014	0.0046***	0.0061***	0.0019***	-0.0034
	(0.0032)	(0.0032)	(0.0032)	(0.0008)	(0.0003)	(0.0003)	(0.0002)	(0.001)	(0.0004)	(0.003)	(0.0002)	(0.0079)
Obs	1281	1281	1281	1332	1332	1332	1332	1332	1332	1332	1332	1332
Pd	0.4277	0.4309	0.4277									

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 5, also illustrates the panel quantile regression results on the relationship between FDIandCO_2 emissions including control variables as shown in Equation (2).We find a significant positive association between GDP and CO_2 emissions across all the quantiles. The magnitude of GDP also increases along the quantiles. This indicates that as the economy expands owing to a rise in industrial activities and consumption, results in increasing CO_2 emissions. This reflects the idea that developing economies prioritize economic growth over environmental concerns and these findings are inline with Utomo et al. (2024) and Hunjra et al. (2024). The magnitude of the GDP^2 decreases for (80^{th} and 90^{th}) quantiles as suggesting that the pollution rates slow down after reaching a threshold level, illustrating the initial and eventual decline in environmental degradation as societies become wealthier and invest in green technologies (Wang et al., 2021; Qamruzzaman, 2024).

In addition to that, GDP^3 captures the complex dynamics like environmental improvement acceleration after higher GDP thresholds. It highlights rapid technological and sustainability advancements, by accelerating pollution reduction with rising revenues from the economies. These findings suggest a flipped U-shaped association between the GDP, GDP^2, and GDP^3 on CO_2, supporting the classic EKC hypothesis, which states that environmental deterioration rises initially as the GDP (per capita income) increases to a certain threshold, and then environmental degradation decreases. Due to this consideration, this research paper's findings dissent with Ganda (2020), whose conclusion did not find an inverted U-shaped curve, but rather an N-shaped curve for the OECD countries. However, Usman and Jahangir (2021) study concurs with the research outcomes by supporting the validity of EKC existence by employing a panel quantile regression model.

Further, FDI shows a positive impact on CO_2particularlyfrom the 10^{th} quantile to the 70^{th} quantile, with only the 80^{th} and 90^{th}quantiles both show negative results. In addition to that, we find that there is a negative association between FDI and CO2 emission in the 80^{th} and 90^{th} quantiles. This negative association between the variables confirms that in a higher quantile, the impact of FDI on CO2 emission becomes negative with a higher significance level. Moreover, FDI shows variances in its effect on CO_2 emissions in terms of magnitude across the quantiles. The possible explanation of the variation in terms of sign and magnitude can be that in emerging economies, the relationship between CO_2emissions and FDI is intricate and multifaceted. On the positive side, FDI can produce cleaner technologies, promote green infrastructure, and encourage regulatory improvements confirming the pollution halo hypothesis which suggests that economies with strict environmental laws foster businesses to embrace greener practices. The results of this research paper correspond with the study of Khan et al. (2023), which explored the influence of FDI inflows on CO_2 emissions in selected African economies. Research discoveries remain varied, with some studies crediting emission reductions to cleaner technologies, while others underscore emission increases due to industrial expansion. Ganda (2020) research paper, came to the conclusion for lower-emission OECD economies that pollution halo and haven hypothesis exist under the examination of evidence. Policy responses should concentrate on implementing stringent environmental standards, fostering sustainable investments, and closely observing FDI projects. However, negative effects entail accelerated emissions from industrialization, higher energy demands, urbanization, and the potential for pollution-intensive activities. This supports the *pollution haven hypothesis* which indicates that businesses emitting high levels of pollution are pulled to countries with relaxed environmental regulations. The interplay between FDI and CO_2 emissions in developing economies requires a careful balance between environmental sustainability and economic growth, necessitating strategic policymaking to harness benefits while mitigating environmental harm.

The impact of FD (DCP) on CO_2 emissions shows varied statistically significant results across all the quantiles. However apart from the 80^{th} and 90^{th} quantiles where the results produce a negative relationship between DCP and CO_2 emission, it shows a statistically significant positive relationship for the remaining quantiles 10^{th} to 70^{th}. The connection between FD and CO_2 emissions in developing economies is an increasingly researched topic. Regulatory frameworks, the type of financial investments, and the existing infrastructure and industrialization are some of the factors that influence the association between FD and CO_2 emissions (Yiadom et., 2022). Rationale behind the positive link between FD and CO2 emission can be that for instance, a positive link exists in areas like industrial expansion, urbanization, and weak environmental policies, while negative connections arise from green investments, greater environmental awareness, and innovation (Shang et al., 2023; Jiang, 2024).

Policy measures regulate credit allocation, strengthen environmental standards, promote green financing, and enhance institutional capacity to direct financial flows toward sustainable investments. The relationship remains highly context-specific, and a structured framework proves crucial to channeling FD into environmentally sustainable practices, as evident in the higher quantiles. This evidence in higher quantiles highlights the nuanced impacts of financial development (Zeng et al., 2024). High-emission sectors such as manufacturing and mining drive increased CO_2 emissions. However, FD encourages environmental progress by funding green technologies and renewable energy projects, helping businesses lower their carbon footprint and adopt cleaner, more efficient production methods (Kharb et al., 2024).

Table 5 further sheds light on renewable energy investment, which produces a negative and significant association with CO_2 emissions across the quantiles. In addition, these findings are consistent with the pooled, fixed, and random effects models. An increase in renewable energy investment decreases the dependence on fossil fuels, which enhances and supports sustainable development and efficient energy. This mitigates climate change by reducing the CO_2 emissions. Our research results align with the findings of (Anwar et al., 2022). The labor status (HC) generates a positive result at the 10^{th} and 20^{th} quantiles followed by a negative relationship at 30^{th} quantile. From 40^{th} to 70^{th} quantile shows a significantly positive association between labor status and CO_2 emissions. The results are varied across all the quantiles, but overall it shows a positive association between HC and CO_2 emissions. As more and more people join the workforce it stimulates the economy which in turn increases the CO_2 emissions. Halliru et al. (2020) study concurs with our results as they find a significantly positive association between CO_2 emissions and CO_2 emissions across all the quantiles.

In general, our results show a significant influence on CO_2 emissions in fixed effects. Itshows the significance that the fixed effects implied when accounting for unobserved factors that remained constant over time (e.g., country-specific policies, technological advancements), the association between renewable energy and CO_2 emissions became apparent. There was an inconsequential impact of pooled and random effects. The lack of significance in pooled and random effects suggested that the connection between renewable energy and CO_2 emissions was too weak to be discerned when examining overall trends or individual variations. Fu et al. (2021) find that the usage of renewable sources of energy greatly decreased CO_2 emissions. This suggest that renewable energy significantly impacted CO_2 emissions, supporting the Porter Hypothesis (1991), which stated that environmental regulations could drive innovation and lead to cost savings, ultimately reducing emissions.

The research reveals that the labor force participation rate (HC) of people age 15+ significantly impacts CO2 emissions. It suggests that as more people aged 15 and above participate in the labor force, CO2 emissions increase. The possible explanation can be that in developing economies, a higher labor force participation rate drives industrial expansion and urban development, leading to increased energy demand and CO2 emissions, especially in energy-intensive industries for instance see(Gao et al., 2024). Urbanization, which often involves increased demand for infrastructure, transportation, and housing, contributes to energy consumption and emissions (Lee and Zhao, 2023). In order to get more benefits, the developing economies should give more focus to the balance growth and environmental protection, integrating human capital development with green technology adoption is crucial. The findings highlight the importance of balance growth and environmental protection in developing economies.

Conclusion:

The study investigate the impact of FDI on CO_2 emissions in developing economies, using panel quantile regression from 1990 to 2022. The study reveals a positive association between CO_2 and GDP emissions, with GDP increasing as the economy expands. GDP^3 shows a negative relationship, indicating environmental improvements accelerate after higher GDP thresholds. This supports the EKC Hypothesis. This study suggest that FDI positively impacts CO_2 emissions across the different estimation techniques (pooled OLS, fixed effects, and random effects) as well as different quantiles. However, the study also suggests that countries with laxer environmental laws may attract businesses producing large amounts of pollution, while countries with stringent laws may encourage greener practices. The connection between FD and CO_2 emissions is negative in higher quantiles. FD can also promote environmental improvements through green technologies and renewable energy projects in developing economies. Further, it is observed that RE investment decreases reliance on fossil fuels, supporting sustainable development, and enhancing energy efficiency.

Appendix

Table A1: Description and source of the variables

List of Variables	Description	Unit	Data Source
CO_2	Carbon emissions	Metric tonnes per capita	WDI (World Bank)
FDI	Foreign direct investment	Net inflows (% of GDP)	WDI (World Bank)
GDP	GDP per capita	GDP per capita (constant 2015 US$)	WDI (World Bank)
DCP	Domestic credit to the private sector by banks *(Financial Development)*	Percentage of GDP	WDI (World Bank)
RE	Renewable energy consumption *(green energy investments)*	Percentage of total final energy consumption	WDI (World Bank)
HC	Labor status	Labor force participation rate (% of population age 15+)	WDI (World Bank)
GHG	Greenhouse gas	Tonnes per capita	WDI (World Bank)

Table A2: List of Countries

Albania	Algeria	Angola	Argentina	Azerbaijan	Bangladesh	Barbados	Benin	Bolivia
Bosnia and Herzegovina	Botswana	Brazil	Burkina Faso	Burundi	Cabo Verde	Cameroon	Central African Republic	Chad

Chile	Colombia	Comoros	Congo, Dem. Rep.	Congo, Rep.	Costa Rica	Cote d'Ivoire	Cuba	Djibouti
Dominican Republic	Ecuador	Egypt, Arab Rep.	El Salvador	Equatorial Guinea	Ethiopia	Gabon	Gambia, The	Ghana
Guinea	Guinea-Bissau	Guyana	Haiti	Honduras	India	Indonesia	Iran, Islamic Rep.	Israel
Jamaica	Jordan	Kazakhstan	Kenya	Korea, Rep.	Lebanon	Lesotho	Madagascar	Malawi
Malaysia	Mali	Mauritius	Mexico	Mozambique	Myanmar	Namibia	Nepal	Nicaragua
Niger	Nigeria	North Macedonia	Pakistan	Panama	Papua New Guinea	Paraguay	Peru	Philippines
Rwanda	Saudi Arabia	Senegal	Sierra Leone	Singapore	South Africa	Sudan	Tanzania	Thailand
Togo	Trinidad and Tobago	Tunisia	Uganda	Uruguay	Venezuela, RB	Yemen, Rep.	Zambia	Zimbabwe

Table A3. Results of normality test

			Jarque-Bera		Shapiro-Wilk		Shapiro-Francia	
	Skewness	**Kurtosis**	**Statistics**	**p-value**	**Statistics**	**p-value**	**Statistics**	**p-value**
CO2	2.29	8.68	6195	0.000	0.714	0.000	0.714	0.000

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