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Original Article

Proxies Affecting Environmental Degradation: A Comparative Analysis Between Developed and Emerging Countries

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Abstract

This study explores the proxies of Environmental Degradation (CO_2 and N_2O) in developed and emerging countries from 2001 to 2021 using panel data regression to accommodate variations over time and across entities. The result confirms the pollution hypothesis in emerging countries where foreign direct investment significantly increases N_2O emissions, highlighting the necessity for stricter environmental regulations. It also reveals that GDP growth correlates with rising CO_2 and N_2O emissions in these regions, due to their early industrial stages, while in developed countries, GDP growth is decoupled from CO_2 emissions, reflecting more sustainable practices. Trade openness in emerging economies further contributes to increased N_2O emissions through deforestation and agricultural expansion. Contrarily, population growth shows a significant negative impact on emissions, suggesting increased efficiency and environmental awareness with higher population densities. These findings emphasize the importance of tailored environmental policies to effectively address the diverse impacts of economic activities on emissions.

Keywords: Environmental Degradation, Environmental Kuznet Curve, Greenhouse Gasses, Pollution Haven Hypothesis

1. Introduction

Environmental degradation fueled by rapid economic growth and human activities, has emerged as a critical global challenge. Industrialization, trade expansion, and urbanization have significantly contributed to environmental issues, including deforestation, air pollution, and the exacerbation of climate change. Central to this crisis is the greenhouse effect, intensified by increasing concentrations of greenhouse gases like carbon dioxide (CO_2) and nitrous oxide (N_2O) (National Geographic, n.d.; NOAA, 2023). These emissions are primarily driven by economic activities, highlighting the interplay between economic growth and environmental sustainability.

Foreign Direct Investment (FDI) plays a pivotal role in shaping the global economy, serving as a catalyst for technological transfer, productivity enhancement, and economic expansion. Several studies underline the positive impacts of FDI, such as fostering innovation and creating skilled employment opportunities in emerging economies (Christoforidis & Katrakilidis, 2022; Rao et al., 2023). In 2022, due to crises like the conflict in Ukraine, rising food and energy prices, and growing public debt, global FDI fell by 12% to $1.3 trillion, highlighting FDI's vulnerability to global shocks. FDI into developed economies fell by 37% to $378 billion, while it increased by 4% in emerging countries, with major emerging economies receiving the most investments (UNCTAD, 2023a). Meanwhile, in Asia the level of FDI inflows in 2021 keeps increasing for the third year in a row despite the pandemic COVID-19 waves, with emerging countries in Asia accounting for 40% of all global FDI inflows, where developed countries like Singapore increased by 31% to $99 billion, Hong Kong expanded 4% to $141 billion, and China climbed by 21% to $181 billion following a 6% growth in 2020 (UNCTAD, 2022) and kept maintaining its FDI inflows at 2022 (UNCTAD, 2023b). However, its environmental implications remain continuous, and the environmental degradation caused by CO_2 increases. In 1950, the United States and Europe accounted for almost 85% of global carbon emissions. However, during the latter part of the 20th century, Asia, especially China, began to take the lead (Faulder, 2021). Meanwhile for N_2O in 2022, global N2O reach a record-breaking of 2.97 billion MTCO2e, it's significantly higher by more than 30% since 1990 and likely more warming than CO_2. Where China began to take the lead, with the United States and India following closely after (Tiseo, 2023).

The influx of FDI also presents challenges, particularly in terms of its environmental impact. The Environmental Kuznets Curve (EKC) suggests that rising in the economy raises emissions and degradation in the environment, but at certain points specifically at high-income levels, it began to take the lead in bettering the environment (Stern, 2017). Conversely, the Pollution Haven Hypothesis (PHH) hypothesizes that industries that produce pollution will shift to areas with laxer environmental laws (Levinson, 2018), The distinction comparing developed and emerging countries emphasized within the research, is found that developed countries, an adverse long-term effect on trade in relation to CO_2 emission. And vice versa, in emerging countries it is shown that CO_2 has a positive long-term relationship to FDI. (Essandoh et al., 2020). Where FDI inflows also increase pollution in addition to benefiting the economy of the host nation (M. A. Khan & Ozturk, 2020), supported by French (1998) that says it is to maximize global investment returns by identifying regions rich in natural resources but characterized by ineffective or weak governance (French, 1998).

Despite extensive research on FDI and its environmental degradation, gaps remain. Most studies focus solely on CO_2, neglecting N_2O's greater warming potential (Tiseo, 2023). Empirical findings on EKC and PHH remain inconclusive, especially between developed and emerging countries' economies (Essandoh et al., 2020). Therefore, this study examines the nexus between FDI and environmental degradation through a comprehensive analysis of multifaceted determinants including GDP, trade openness, manufacturing, political stability, urbanization, and population growth by using CO_2 and N_2O emissions as the degree of environmental degradation in 100 emerging and 31 developed countries from 2001 to 2021, this study offers a more nuanced perspective on the proxies of environmental degradation, benefiting policymakers by providing insights to balance economic growth and environmental sustainability, aiding environmentalists in advocating for stronger regulations, supporting economists in understanding the development FDI environment nexus, guiding investors towards sustainable investment decisions, and serving as a valuable reference for academics and researchers exploring eco-economics, international business, and long-term growth.

2. Literature Review

2.1. Environmental Degradation

Environmental degradation, caused by human activities like industrialization and over-exploitation of natural resources, leads to ecological degradation, pollution, acid rain, ozone depletion, and reduced biodiversity (Chen et al., 2020). Earth's atmosphere and ocean temperatures increase due to natural processes, greenhouse gas emissions, and long-wave radiation, affecting precipitation patterns, glacier melting, soil and sea level rise, and ecosystem balance, causing climate change. N_2O and CO_2 contribute to the greenhouse effect by absorbing solar radiant heat energy, leading to global warming due to increased greenhouse gases (Chen et al., 2020).

In honor of Simon Kuznet, the Environmental Kuznets Curve (EKC) is frequently utilized to illustrate the connection between environmental quality and economic growth, it hypothesizes that as economic growth occurs, environmental degradation and pollution initially increase but eventually decrease at higher income levels. The EKC represents this relationship as a U-shaped inversion curve of income per capita and proposes that income inequality would increase and then decrease in the course of economic development (Stern, 2004).

Over the years, the academic community has extensively examined the presence of EKC, with numerous studies utilizing CO_2 and N_2O emissions as primary indicators for assessing environmental degradation and the existence of EKC. One study discovered a significant correlation between CO_2 emissions and economic growth in the long run verifying the presence of EKC (Shahbaz et al., 2019). Another study using N_2O found the inverted U-shaped relationship in the case of railway transport verifying the presence of EKC (Hassan & Nosheen, 2019).

Conversely, Pollution Haven Hypotheses (PHV), hypothesize that industries that produce pollution will move to areas with laxer environmental laws (Levinson, 2018). Where developing countries have attracted investment from developed countries due to low costs for the environment and labor, leading to the transfer of pollution-intensive enterprises to lower-priced developing countries for profit maximization (Zhang & Wang, 2021), meanwhile, the opposition to PHV is Pollution Halo (PHL) says that FDI (or others economics driven) positively impact affects the environment (Repkine & Min, 2020), it can also promote environmental sustainability in highly developed economies or regions (Aust et al., 2020). In this study, drawing on prior research, environmental degradation is assessed by examining CO_2 and N_2O emissions (Trang et al., 2023).

2.2. Foreign Direct Investment (FDI)

The total amount of inbound investments made by non-resident investors in a reporting economy is known as FDI net inflows. This includes the aggregate of equity capital, profits that are reinvested, and additional types of capital (Worldbank, 2022.).

FDI is a key factor in economic development and expansion, it can enhance technology, boost productivity, and stimulate economic expansion (Christoforidis & Katrakilidis, 2022; Rao et al., 2023; Sakali, 2015; Tsoy & Heshmati, 2023). Meanwhile environmental issues can not only jeopardize investors' financial outcomes but also damage the company reputation, the strategic decisions made by companies can significantly influence public perception regarding their commitment to social and environmental concerns. Consequently, making strategic choices that prioritize environmental sustainability is crucial (Carolina Rezende De Carvalho Ferrei et al., 2016; Hamilton & Eriksson, 2011).

Some studies claim that economic growth can increase the degradation of the environmental (Shahbaz et al., 2019), and CO2 emissions and GDP, FDI, and financial development (FD) are correlated, the results of the analysis demonstrated that FD, GDP, and FDI statistically significantly affect CO2 emissions (Nasir et al., 2019). A study by Essandoh et al., (2020) discovers potential differences between developed and emerging countries, concluding that CO2 emissions have a long-term negative relationship with FDI inflows for developed nations, but a positive relationship with it for emerging countries (Essandoh et al., 2020). Other studies have found FDI and CO2 emissions positively correlated in some countries or areas, they suggest that lax environmental regulations in the FDI is drawn to the host economy, which ultimately causes environmental deterioration in that nation (Sarkodie & Strezov, 2018; Shahbaz et al., 2018; Sun et al., 2017).

By using FDI inflows (BoP, Current US$) as FDI where the data are obtained from Worldbank, the hypotheses are presented:

H_{1a}: FDI positively significant to CO_2 in developed countries.
H_{1b}: FDI positively significant to N_2O in developed countries.
H_{1c}: FDI positively significant to CO_2 in emerging countries.
H_{1d}: FDI positively significant to N_2O in emerging countries.

2.3. Economic Growth (GDP)

GDP is the total gross value added by every producer in resident in a country, excepting subsidies that are not part of the product value and including product taxes. The computation does not account for the exhaustion and deterioration of natural resources or the deterioration of man-made assets (Worldbank, 2022.).

The EKC asserts that economic expansion initially results in increased pollution and environmental deterioration, but as income levels rise, economic growth eventually results in environmental improvements (Stern, 2017).

A study in Ghana indicated that the long-term effects of GDP and energy consumption on CO2 emissions are significant. The results demonstrated that a 0.73% increase in CO2 emissions corresponds with a 1% increase in GDP (Asumadu-Sarkodie & Owusu, 2017). The results of a European study show that, to differing degrees, CO2 emissions and economic growth are positively correlated with population size, urbanization, foreign direct investment, and energy intensity (Pham et al., 2020).

However, the other study shows that a change in the high level of per capita income in developed nations appears to have led to a decrease in CO2 emissions. (Benzerrouk et al., 2021), it is in line with the one who pioneered the study of EKC which confirms the EKC hypotheses (Grossman & Krueger, 1995).

By using GDP (current US$) from Worldbank as economic growth, therefore the hypotheses are presented:

H_{2a}: GDP positively significant to CO_2 in developed countries.
H_{2b}: GDP positively significant to N_2O in developed countries.
H_{2c}: GDP positively significant to CO_2 in emerging countries.
H_{2d}: GDP positively significant to N_2O in emerging countries.

2.4. Trade Openness

The term "trade openness" describes the economic direction of a nation; an outward orientation maximizes trade possibilities, while an inward orientation avoids them. Important trade policy choices concern infrastructure, technology, scale economies, import-export, trade obstacles, and market competitiveness (UNESCEWA, 2015). The total value of goods and services imported and exported, expressed as a percentage of GDP, is what is known as trade (% of GDP) (Alotaibi & Mishra, 2014; Worldbank, 2023).

A study indicates a link between CO2 emissions and trade. The outcomes demonstrate that greater trade liberalization results in worse environmental conditions (Mahrinasari et al., 2019). Trade openness reduces environmental deterioration among lower-middle-income groups, the research examines the impact of trade openness on CO2 emissions. Furthermore, trade liberalization exacerbates environmental deterioration among the upper-middle class (Wang & Wang, 2021).

By using trade (% of GDP) from Worldbank as trade openness, therefore the hypotheses are presented:

H$_{3a}$: Trade Openness positively significant to CO_2 in developed countries.
H$_{3b}$: Trade Openness positively significant to N_2O in developed countries.
H$_{3c}$: Trade Openness positively significant to CO_2 in emerging countries.
H$_{3d}$: Trade Openness positively significant to N_2O in emerging countries.

2.5. Manufacturing

Manufacturing involves transforming materials and information into products to fulfill human needs, is a crucial economic activity that generates wealth, and contributes significantly to employment in any country (Chryssolouris, 2006). According to ISIC, Manufacturing is an economic activity, whether it's power-driven or manual, and whether it's in a factory or household (ISIC, 2024).

The process on manufacturing dividing into two groups, phase-changing which uses electricity and natural energy such as gas, and non-phase-changing, which mainly uses electricity (Chryssolouris, 2006).

Study finds that carbon emissions in manufacturing are mainly caused by the consumption of electrical energy, tools, coolant liquids, and the production, disposal, and transportation of materials. It identifies electrical energy as the most significant contributor to carbon emissions at both the process and machine levels (Panagiotopoulou et al., 2022). The expansion of manufacturing leads to the production of high-energy products and results in pollution through the emission of toxic gases such as CO_2, N_2O, and others, ultimately deteriorating environmental quality (López, 1994; Torras & Boyce, 1998).

The research employs the STIRPAT framework and data from OECD nations to examine CO_2 emissions. Findings indicate that consumption of non-renewable energy elevates emissions, whereas utilization of renewable energy reduces them. The Kuznets curve posits that energy evolution can significantly contribute to both diminishing non-renewable energy consumption and alleviating climate change (Shafiei & Salim, 2014).

By using manufacturing, value added (% of GDP) from Worldbank as manufacturing, therefore the hypotheses are presented:
H$_{4a}$: Manufacturing positively significant to CO_2 in developed countries.
H$_{4b}$: Manufacturing positively significant to N_2O in developed countries.
H$_{4c}$: Manufacturing positively significant to CO_2 in emerging countries.
H$_{4d}$: Manufacturing positively significant to N_2O in emerging countries.

2.6. Political Stability

The governance system and political regime significantly impact environmental sustainability. Overexploitation of natural resources can lead to depletion and degradation. The ruling party's political orientation towards environmental issues influences these issues, with loose laws promoting degradation (Agheli & Taghvaee, 2022).

A sustainable environment cannot be ensured by political stability alone, but it does enable nations to handle environmental crises and enact suitable protective measures that promote sustainability and halt degradation (Agheli & Taghvaee, 2022)

A study in ten politically stable economies spans the years 1991–2019 analysis the relationship between political risk and CO2 emissions spans the years 1991–2019. The findings indicate that while political risk lowers environmental quality in Australia, Germany, and Denmark, it improves it in Norway, Sweden, Canada, and Switzerland (Adebayo et al., 2022).

Over time, a decline in the ecological footprint is caused by political stability and the absence of violence, which contribute to the reduction of environmental degradation. Its show by a study conducted in the Middle East and North African countries, an increase of one unit will ultimately cause the ecological footprint to decrease by 0.548%, although the findings indicate that short-term impacts (Al-Mulali & Ozturk, 2015).

By using Political stability and absence of violence/terrorism (estimate) from Worldbank as political stability, therefore the hypotheses are presented:

H_{5a}: Political Stability positively significant to CO_2 in developed countries.
H_{5b}: Political Stability positively significant to N_2O in developed countries.
H_{5c}: Political Stability positively significant to CO_2 in emerging countries.
H_{5d}: Political Stability positively significant to N_2O in emerging countries.

2.7. Urbanization

The surge in economic prosperity has led to a swift expansion of the urban populace, thereby intensifying the energy demand and consequently escalating carbon emissions (K. Khan et al., 2020), due to economic development, the population of cities has grown quickly, putting pressure on consumption energy causing rise of CO_2 (Al-mulali et al., 2012).

A study conducted in Vietnam has found that urbanization is a significant factor influencing CO2 emissions. The research demonstrates that the variables have a cointegration relationship, highlighting an issue in the region due to the concentration of significant economic activities in Hanoi and Ho Chi Minh City. This concentration resulting to a marked an increase in the quantity of motorbikes and cars, contributing to the rise in emissions (Shahbaz et al., 2019). Also, an investigation conducted in MENA Countries found that urbanization and ecological footprint are cointegrated, verifying that the variables utilized have a persistent relationship, the result showed that urbanization is one of the main factors causing environmental degradation ultimately due to its beneficial impact on the ecological footprint over time (Al-Mulali & Ozturk, 2015).

Conversely, a study discovered that CO2 emissions and urbanization are correlated with an environmental Kuznets curve, suggesting the environmental impact diminishes at higher levels of urbanization (Shafiei & Salim, 2014).

By using urban population growth (annual %) from Worldbank as urbanization, therefore the hypotheses are presented:

H_{6a}: Urbanization positively significant to CO_2 in developed countries.
H_{6b}: Urbanization positively significant to N_2O in developed countries.
H_{6c}: Urbanization positively significant to CO_2 in emerging countries.
H_{6d}: Urbanization positively significant to N_2O in emerging countries.

2.8. Population Growth

The emission that is cause for concern is typically the CO_2 emission, which is associated with human activity. Conversely, as the human population grows, so do anthropogenic activities, which contribute to an increase in CO_2 emissions (Sulaiman & Abdul-Rahim, 2018), a study conducted in the USA finds that increasing rising population levels mostly result in higher per-capita energy use, where raise of 1 percent of population causes CO2 levels to rise by 0.593% GLM (I. Khan et al., 2021).

It is asserted that, over the coming decades, a rise in population may lead to increased energy consumption and consequently, a surge in CO_2 emissions (Liddle, 2015). A study indicates that increases in CO_2 emissions, which result from a variety of economic and consuming activities impacted by demographic considerations, occur in tandem with population growth.(Cole & Neumayer, 2004).

By using population growth (% annual) from Worldbank as population growth, therefore the hypotheses are presented:

H_{7a}: Population Growth positively significant to CO_2 in developed countries.

H_{7b}: Population Growth positively significant to N_2O in developed countries.
H_{7c}: Population Growth positively significant to CO_2 in emerging countries.
H_{7d}: Population Growth positively significant to N_2O in emerging countries.

3. Methods

3.1. Data

The study considers several control variables including GDP, trade, manufacturing, political stability, urbanization, and population growth rate. The population data is taken from the previous study by Benzerrouk et al. (2021) performed in 31 developed and 100 emerging countries (Benzerrouk et al., 2021) from the Worldbank data, which spans the years 2001 to 2021 and it's winsorized at 1% to reduce bias (Glen, 2016).

3.2. Empirical Model

Following the empirical model from the previous study by Trang et al. (2023) by using fixed effects models to determine the nexus between FDI and environmental degradation here is the regression model that will be used in this study (Trang et al., 2023):

$$CO_{2\,i,t} = \alpha + \beta_1 FDI_{i,t} + \beta_2 GDP_{i,t} + \beta_3 Trade_{i,t} + \beta_4 MFG_{i,t} + \beta_5 POL_{i,t} + \beta_6 Urban_{i,t} + \beta_7 Popgrowth_{i,t} + \varepsilon_{i,t}$$

$$N_2O_{i,t} = \alpha + \beta_1 FDI_{i,t} + \beta_2 GDP_{i,t} + \beta_3 Trade_{i,t} + \beta_4 MFG_{i,t} + \beta_5 POL_{i,t} + \beta_6 Urban_{i,t} + \beta_7 Popgrowth_{i,t} + \varepsilon_{i,t}$$

Table 1. Operational variables

Variable types	Acronyms	Variables Names
Dependent	CO_2	CO_2 emissions (MT / capita)
	N_2O	Nitrous oxide emissions (thousand MT CO_2 equivalent)
Independent	FDI	Foreign direct investment, net inflows (BoP, current US$)
	GDP	GDP (current US$)
	Trade	Trade (% of GDP)
	MFG	Manufacturing, value added (% of GDP)
	POL	Political Stability and Absence of Violence/Terrorism: Estimate (Index)
	Urban	Urban population growth (annual %)
	Popgrowth	Population growth (annual %)

4. Results and Discussion

This research utilizes the fixed effects model within a panel data framework to investigate the proxies of environmental degradation across encompassing 131 countries was examined as a whole. Subsequently, the researcher partitioned the dataset into categories based on the distinction between developed and emerging countries. Throughout the analysis of the panel data, the researchers identified issues of autocorrelation, heteroscedasticity, and cross-sectional dependence. To address these problems, the researchers utilized Driscoll-Kraay Standard Errors regression.

4.1. Descriptive Statistics

The study has summarized the variables using descriptive statistics, focusing on the maximum, minimum, mean, and standard deviation values. Each variable's statistical description in this study is presented in the following table:

Table 2. Descriptive Statistics

Variables	Country Group	Mean	Std_Dev	Median	Min	Max
CO2	Developing	365887.30	909776.15	65666.30	1352.30	5152968.24
	Emerging	132472.25	525593.76	11735.80	171,67	5152968.24
N2O	Developing	3355.96	9253.22	729.46	11.02	52099.72
	Emerging	1250.60	4860.66	210.76	0	52099.72
FDI	Developing	35.55	57.05	12.18	-12.34	242.25
	Emerging	5.03	20.02	0.78	-12.34	242.25
GDP	Developing	1140841.71	1974008.65	353361.04	4069.52	9965147.71
	Emerging	187555.61	750049.67	27139.23	733.24	9965147.71
Trade	Developing	109.71	79.80	81.15	22.81	351.63
	Emerging	76.33	35.88	68.98	22.81	220.41
MFG	Developing	14.37	5.87	13.37	1.52	32.01
	Emerging	13.09	6.08	13.27	1.52	32.01
POL	Developing	0.82	0.55	0.95	-1.63	1.50
	Emerging	-0.37	0.85	-0.28	-2.52	1.41
Urban	Developing	0.94	0.72	0.86	-1.28	5.32
	Emerging	2.37	1.74	2.34	-1.28	7.06
Popgrowth	Developing	0.72	0.71	0.59	-1.22	5.32
	Emerging	1.60	1.37	1.49	-1.22	6.40

Based on table 2 CO_2 emissions exhibit substantial differences between developed and emerging countries. The mean CO_2 emission in developed countries is 365887.30, with a standard deviation of 909776.15, indicating significant variability among these nations. The median emission is 65666.30, which is notably lower than the mean, suggesting a right-skewed distribution. Emission values range from a minimum of 1352.30 to a maximum of 5152968.24, highlighting the presence of outliers with exceptionally high emissions. In contrast, emerging countries have a mean CO2

emission of 132472.25 with a standard deviation of 525593.76. The median emission is 11735.80, much lower than the mean, reflecting a similar right-skewed distribution. Emission values in these countries range from a minimum of 171.67 to a maximum of 5152968.24. These findings indicate that while both groups exhibit wide ranges and high variability, developed countries generally have higher average CO2 emissions.

Nitrous oxide emissions also differ significantly between developed and emerging countries. Developed countries report a mean N_2O emission of 3355.96 with a standard deviation of 9253.22, indicating considerable variability. The median emission is 729.46, lower than the mean, suggesting a right-skewed distribution. Emission values range from a minimum of 11.02 to a maximum of 52099.72. Emerging countries, on the other hand, have a mean N_2O emission of 1,250.60 with a standard deviation of 4860.66. The median emission is 210.76, with values ranging from zero to a maximum of 52099.72. This indicates that developed countries generally have higher and more variable N2O emissions compared to emerging countries.

Foreign direct investment shows considerable disparity between developed and emerging countries. In developed countries, the mean FDI is 35.55 with a standard deviation of 57.05, reflecting substantial differences in investment levels. The median FDI is 12.18, suggesting that half of the countries receive less than this amount. The range of FDI extends from zero to a maximum of 242.25. In emerging countries, the mean FDI is significantly lower at 6.06 with a standard deviation of 12.20. The median FDI is zero, indicating that many emerging countries receive little to no foreign investment. The range also extends from zero to a maximum of 242.25. These statistics highlight the greater average FDI received by developed countries.

GDP exhibits significant differences between developed and emerging countries. Developed countries have a mean GDP of 1140,841.71 with a very high standard deviation of 1974008.45, reflecting vast economic disparities. The median GDP is 353361.41, which is much lower than the mean, indicating a right-skewed distribution. GDP values range from a minimum of 4069.95 to a maximum of 9965741.17. Emerging countries have a mean GDP of 187555.61 with a standard deviation of 750049.47. The median GDP is 27139.23, with values ranging from a minimum of 733.24 to a maximum of 9965,741.17. These findings indicate that while both groups exhibit significant economic disparities, developed countries have considerably higher average GDP.

Trade values differ markedly between developed and emerging countries. In developed countries, the mean trade value is 109.71 with a standard deviation of 79.70. The median trade value is 81.15, with values ranging from a minimum of 22.21 to a maximum of 351.63. Emerging countries have a mean trade value of 72.29 with a standard deviation of 62.01. The median trade value is 51.30, with values ranging from a minimum of 0.49 to a maximum of 220.41. These statistics indicate that developed countries generally engage in higher volumes of trade compared to emerging countries.

The manufacturing sector's contributions vary between developed and emerging countries. Developed countries have a mean manufacturing value of 14.37 with a standard deviation of 5.87. The median value is 13.37, with values ranging from a minimum of 1.52 to a maximum of 32.37. In emerging countries, the mean manufacturing value is 12.89 with a standard deviation of 6.01. The median value is 12.41, with values ranging from 1.58 to 32.87. This suggests that while manufacturing is an important sector in both groups, developed countries tend to have a slightly higher average.

Political stability, measured by an index, also shows variation between developed and emerging countries. Developed countries have a mean political stability index of 0.82 with a standard deviation of 0.75. The median index value is 0.55, with values ranging from a minimum of 0.04 to a maximum of 4.63. In emerging countries, the mean political stability index is 0.37 with a standard deviation of 0.83. The median index value is 0.16, with values ranging from -2.21 to 18.28. These figures indicate that developed countries generally have higher political stability compared to emerging countries.

Urbanization levels differ between the two groups. Developed countries have a mean urbanization level of 0.94 with a standard deviation of 0.72. The median value is 0.72, with values ranging from zero to 3.52. In emerging countries, the mean urbanization level is higher at 1.38 with a standard deviation of 1.48. The median value is 0.89, with values ranging from zero to 13.40. This suggests a more varied urbanization level in emerging countries, with some areas experiencing rapid urban growth.

Population growth rates show significant differences between developed and emerging countries. Developed countries have a mean growth rate of 0.72 with a standard deviation of 0.71. The median growth rate is 0.59, with values ranging from -1.22 to 5.32. The mean growth rate in emerging countries is 1.60 with a standard deviation of 1.37. The median growth rate is 1.49, with values ranging from -1.63 to 6.16. These statistics reflect higher and more varied population growth rates in emerging countries compared to developed ones.

4.2. Result and Empirical Interpretation

Table 3. Panel Data Regression

Independent Variable	All Countries				Developed Countries				Emerging Countries			
	CO_2		N_2O		CO_2		N_2O		CO_2		N_2O	
	Coef,	p	Coef,	p	Coef,	p	Coef,	p	Coef,	p	Coef,	p
FDI	146.315	0.094	1.858	0.023	63.620	0.272	0.314	0.066	512.488	0.061	8.190	0.027
GDP	0.041	0.001	0.002	0.000	0.012	0.372	0.000	0.000	0.043	0.019	0.002	0.000
Trade	-182.403	0.001	-0.938	0.023	358.330	0.071	0.990	0.358	79.580	0.115	0.826	0.004
MFG	914.983	0.003	7.843	0.055	-103.714	0.870	-0.607	0.883	249.642	0.534	4.419	0.237
POL	9.025.060	0.025	44.892	0.058	24.545.282	0.261	73.372	0.415	5.310.551	0.048	7.892	0.477
Urban	5.146.202	0.024	37.353	0.030	-7.636.264	0.523	197.784	0.003	8.654.769	0.005	33.053	0.046
Popgrowth	-9.773.349	0.004	-59.032	0.001	13.730.655	0.286	-166.656	0.014	-13.856.771	0.000	-51.058	0.004
Adj. Rsquared	-0.006		0.647		-0.073		-0.029		0.014		0.779	
Prob>F	0.000		0.000		0.000		0.000		0.000		0.000	

In all countries, the result of Prob>F is 0.000 indicating that both models are statistically significant, with the Adjusted R-squared values are -0.006 for CO_2 and 0.647 for N_2O. This indicates that the CO_2 model does not fit well, while the model for N_2O explains approximately about 64.7% of the variability in emissions, after dividing the data into two categories of the countries, developed and emerging, it appears that both Adjusted R-squared are negative for developed countries, -0.073 for CO_2 and -0.029 for N_2O, suggesting that the models do not adequately explain the variability in emissions. Conversely, in emerging countries, the Adjusted R-squared values are -0.014 for CO_2 and 0.779 for N_2O, indicating that the model for CO_2 does not fit well, while the model for N_2O fits well and explains a significant portion of the variability in emissions. These findings highlight the varying effectiveness of the independent variables in explaining emissions across different country categories. The models are most effective in explaining N_2O emissions in emerging countries, while the models for CO_2 emissions in all countries and emerging countries, as well as both emission models in developed countries, do not perform well, indicating the need for better models or additional variables to accurately capture the factors influencing emissions.

For FDI in the all-countries model, the analysis reveals that FDI has a positive relationship with a coefficient of 146.315 but it is not significant with a p-value of 0.094 in the CO_2 model. Meanwhile, on N_2O model shows a positive but relatively low relationship with a coefficient of 1.858, which is significant with a p-value of 0.023, these findings contrast to a previous study which suggests that FDI is positive and significant to CO_2 and negatively and not significantly to N_2O (Trang et al., 2023). When dividing into two group countries categories (developed and emerging), on the CO_2 model, FDI shows a positive but not significant relationship in both countries group, with a coefficient of 63.62 and p-value of 0.272 in developed countries, and coefficient of 512.488 and a p-value of 0.061 in emerging countries. Meanwhile, in the N_2O model, a positive relationship is found in both group countries but it is only significant in the emerging countries, with a coefficient of 0.314 and p-value of 0.066 in emerging countries, and a coefficient of 8.190 with a p-value of 0.027 in emerging countries which means that hypotheses H_{1a}, H_{1b}, and H_{1c} are rejected, and H_{1d} are supported. The findings support the pollution haven hypothesis, indicating that countries with weaker environmental regulations attract more polluting industrial investments. The evidence is shown by the significant positive relationship between FDI and N_2O emissions in emerging countries. However, no relationship is found for CO_2, suggesting the necessity to improve the models for FDI's impact assessment on CO_2 emissions. Another suggestion for emerging countries is to adopt tighter environmental policies to ensure that incoming FDI complies with environmental sustainability. The suggestion will encourage investment in cleaner and more energy-efficient industries to mitigate emission impacts.

For GDP in the all-countries model, the analysis reveals that GDP in both models shows a positive and significant relationship, where the GDP on CO_2 models has a coefficient of 0.041

with a p-value of 0.001, this in line with the previous study that says GDP is positive and significant to CO_2 with the significant level at 5% (Trang et al., 2023), in the N_2O models also shows a positive and significant relationship with a coefficient of 0.002 and a p-value of 0.000 which contrasts with the previous study that says GDP are negatively and not significant to N_2O (Trang et al., 2023). When divided into two group categories (developed and emerging), the GDP on the CO_2 models in developed countries shows a positive but not significant relationship with a coefficient of 0.012 and a p-value of 0.372 meanwhile, in emerging countries it shows a positive significant relationship with a coefficient of 0.043 and a p-value of 0.019. The N_2O models show a positive significance for both groups' countries with a coefficient of 0.000 and a p-value of 0.000 in developed countries and a coefficient of 0.002 and a p-value of 0.000 in emerging countries which means that hypotheses H_{2a} are rejected and H_{2b}, H_{2c}, H_{2d} are supported. The significant positive relationship between GDP and both CO_2 and N_2O emissions in emerging countries suggests that these countries are in the initial phase of economic growth where industrial activities and emissions rise with increasing GDP. In contrast, the insignificant relationship between GDP and CO_2 in developed countries may indicate that these countries have reached a stage where economic growth no longer leads to increased emissions, aligning with the later phase of the EKC where emissions begin to decline with further economic growth. This suggests that emerging countries should engage in public-private partnerships to develop sustainable projects, implement environmental taxes as a public policy tool for reducing emissions and its effects on pollutants (Sulisnaningrum et al., 2023), offer incentives such as tax breaks for adopting energy-efficient technologies, and actively participate in international environmental agreements to demonstrate a commitment to global standards. These strategies align with previous studies showing that differentiated strategies in private sectors can enhance environmental performance (Juniarti et al., 2021) while signaling a strong commitment to sustainability, attracting investments that support both economic growth and environmental protection.

For Trade in the all-countries model, the analysis reveals that trade in both models show a negative significant relationship where trade on CO_2 models has a coefficient of -182.403 and a p-value of 0.001. Also, N_2O models have a coefficient of -0.938 and a p-value of 0.023, These findings contrast with a previous study that suggests trade is positively and significantly related to CO_2 and positively but not significantly related to N_2O (Trang et al., 2023). When divided into two group categories (developed and emerging), the CO_2 models show a positive but not significant relationship in both countries groups with a coefficient of 358.330 and a p-value of 0.071 in developed countries and a coefficient of 79.580 with a p-value of 0.115 in emerging countries, meanwhile on the N_2O models it shows a positive relationship is found in both country groups but it is only significant in the emerging countries group with a coefficient of 0.990 and a p-value of 0.358 in developed countries and a coefficient 0.826 with a p-value of 0.004 in emerging countries which means hypotheses H_{3a}, H_{3b}, and H_{3c} are rejected meanwhile, hypotheses H_{3d} are supported. The significant positive relationship between trade and N_2O emissions in emerging countries could be attributed to increased agricultural activities and deforestation driven by trade demands. Previous studies have demonstrated that major sources of N_2O emissions are the exploitation of agricultural production, such as the cutting and clearing of tropical forests, and household consumption processes (Chapuis-Lardy et al., 2007; Vallero, 2016), This is supported by findings from Leblois et al. (2017) showing that trade is a major driver of deforestation, particularly in emerging countries where increased agricultural exports at the national level lead to a reduction in forest area (Leblois et al., 2017). This suggests emerging countries should invest in reforestation and afforestation to restore degraded lands, increase forest cover, offset emissions, and protect biodiversity, these initiatives mitigate the environmental impact of trade-driven agricultural activities and promote long-term sustainability.

For MFG in the all-countries model, the analysis reveals that MFG has a positive relationship in both models but its only significance in CO2 models with a coefficient of 914.983 and a p-value of 0.003 it's not in line with the previous study that finds there are negative relationship but not significant in manufacturing related to CO2 (Trang et al., 2023), and for N2O its not significant with a coefficient of and a p-value of 0.055 whereas the previous study says that manufacturing have a negative relationship and is not significant to N2O (Trang et al., 2023). When divided into two group categories (developed and emerging), the CO2 models it shows a negative but not significant relationship in developed countries with a coefficient of -103.714, p-value of 0.870, and a positive but not significant relationship in emerging countries where the coefficient are 249.642, p-value 0.534. For the N2O models, it finds a negative and not significant relationship in developed countries with a coefficient of -0.607 and p-value of 0.883, and a positive but not significant relationship is found in emerging countries with a coefficient of 4.419 and p-value of 0.237 which means hypotheses H_{4a} H_{4b} H_{4c} and H_{4d} are rejected. This suggests that the manufacturing sector's influence on emissions is not substantial in both developed and emerging countries, thus not supporting hypotheses.

For POL in the all countries model, POL shows a positive and significant relation in CO2 models with a coefficient of 9205.06 and a p-value of 0.025, meanwhile for N2O it shows a positive but not significant relationship with a coefficient of 44.892 and p-value of 0.058, This is in contrast to previous study says that political stability have negative effects and not significant to CO2 and N2O (Trang et al., 2023). When divided into two group categories (developed and emerging), the CO2 models show a positive and not significant relationship in developed countries with a coefficient of 24545.282 and a p-value of 0.261, and a positive significant relationship in emerging countries, with a coefficient of 5310.551 and a p-value of 0.048. For the N2O models, both country groups showed a positive relationship but not significant with a coefficient of 73.372 and a p-value of 0.415 in developed countries, and a coefficient of 7.982 with a p-value of 0.477 in emerging countries which means hypotheses H_{4a} H_{4b} and H_{4d} are rejected, meanwhile H_{4c} are supported. These findings suggest that political stability in emerging countries is linked to an increase in CO2 emissions. While a stable political system can manage environmental crises and adopt protection policies, it alone is not enough for environmental sustainability. This supports the Pollution Haven Hypothesis, where economic growth in stable political environments often prioritizes industrial activities over environmental concerns, leading to higher emissions. Therefore, stringent environmental regulations and comprehensive policies are essential to balance growth and sustainability.

For Urban in all countries, it reveals that urbanization has a positive and significant impact on both models, with a coefficient of 5146,202 and a p-value of 0,024 in CO2 models and a coefficient of 37,353 with a p-value of 0,03 in N2O models these findings contrast with the previous study that finds urbanization model is not significant in CO2 and N2O although it has a positive relation to CO2 and negative relation to N2O (Trang et al., 2023). When divided into two groups of countries (developed and emerging), it finds that CO2 models have a negative but not significant with coefficient of -7636,264 and a p-value of 0,523 in developed countries. Meanwhile, in emerging countries, it finds that urbanization has a positive and significant relation to CO2 with a coefficient of 8654,769 with a p-value of 0,005. For N2O models it finds both country group has a positive and significant relation with a coefficient of 197,784, a p-value of 0,003 in emerging countries, and a coefficient of 33,053 and a p-value of 0,046 which means, hypotheses H_{6a} are rejected and H_{6b} H_{6c} H_{6d} are supported. The findings in emerging countries may be due to uneven economic growth between urban and rural areas, leading to concentrated economic activities in cities and increased CO2 and N2O emissions. In contrast, balanced economic growth in developed countries results in urbanization not significantly affecting CO2 emissions. However, the positive relationship between urbanization and N2O emissions in developed countries indicates that urban activities still contribute to higher N2O emissions. This suggests that emerging countries should promote balanced regional development by encouraging economic growth in rural areas to reduce urban concentration and emissions. Additionally, emerging and developed countries should strengthen urban planning by focusing on sustainable practices, such as green spaces, efficient public transportation, and sustainable infrastructure, to reduce emissions linked to urbanization.

For Popgrowth in all countries, the analysis reveals that population growth has a significant negative impact on both CO2 and N2O emissions, with a coefficient of -9773.349, a p-value of 0.004 in the CO2 model, and a coefficient of -59.032, a p-value of 0.001 in the N2O model. These findings contrast with previous studies that suggest population growth has a negative relation but is not significant in both models (Trang et al., 2023). When divided into two groups of countries (developed and emerging), the CO2 model shows that in developed countries, population growth has a positive but not significant relationship with CO2 emissions, with a coefficient of 13730.655 and a p-value of 0.286. In contrast, in emerging countries, population growth has a significant negative relationship with CO2 emissions, with a coefficient of -13856.771 and a p-value of 0.000. For the N2O models, population growth has a significant negative relationship with N2O emission in both countries groups with a coefficient of -166.656 and a p-value of 0.014 in developed countries and a coefficient of -51.058 and a p-value of 0.004 in emerging countries which means hypotheses H_{7a}, H_{7b}, H_{7c} and H_{7d} are rejected. These findings indicate that population growth tends to reduce emissions of both CO2 and N2O in emerging countries, while in developed countries, this effect is observed only for N2O. This suggests that as populations increase, there is a collective awareness and proactive action towards energy efficiency in both residential and industrial sectors such as the adoption of eco-friendly technologies like LED lighting and lower GWP refrigerants, adoption of renewable energy sources like solar panels and nuclear power and awareness of societal commitment to recycling various materials to preserve the environment.

Based on the analysis of this empirical study on the environmental impact of economic activities confirms the pollution haven hypothesis in emerging countries, where FDI significantly contributes to N2O emissions, underscoring the need for stricter environmental regulations to mitigate the adverse effects of polluting investment. It also shows that GDP growth in emerging countries correlates with rising CO2 and N2O emissions, reflecting their early industrial development stages. In contrast, developed countries show a decoupling of GDP growth from CO2 emissions, indicating advanced stages of sustainable practices. Additionally, trade openness particularly in emerging economies, exacerbates deforestation and agricultural expansion, leading to increased N2O emissions.

Conversely, population growth displays a unique trend with a significant negative correlation with emissions, suggesting that higher population densities might be associated with more efficient use of resources and/or collective awareness and technological advancement toward environment sustainability. Meanwhile, the varied effects of urbanization and political stability on emissions in different economies suggest the need for region-specific environmental policies to address these issues effectively.

5. Conclusion

This study aimed to explore the intricate relationship between various economic and environmental aspects and how they affect CO_2 and N_2O emissions across different country classifications. Through rigorous regression analysis, this study has provided significant insights into how factors such as Foreign Direct Investment (FDI), Gross Domestic Product (GDP), trade, manufacturing, political stability, urbanization, and population growth influence GHG emissions both developed and emerging countries. The findings demonstrate a marked difference in the explanatory power of the models between developed and emerging countries. Notably, the model for N_2O emissions significantly accounted for approximately 77.9% of the variability in emissions within emerging countries. This indicates that N_2O emissions in these countries are highly sensitive to changes in the studied economic and environmental factors. Conversely, the models for both CO_2 and N_2O emissions performed poorly in developed countries, suggesting that these factors are less predictive of emission trends in these regions.

For FDI the findings support the pollution haven hypothesis, showing that countries with weaker environmental regulations attract more polluting industrial investments, as evidenced by the positive relationship between FDI and N_2O emissions in emerging countries. However, there is no significant relationship for CO_2, suggesting the need to improve FDI impact models on CO_2 emissions. Emerging countries should adopt tighter environmental policies to ensure incoming FDI complies with sustainability standards, encouraging cleaner, energy-efficient investments to reduce emissions.

For GDP the positive relationship between GDP and both CO_2 and N_2O emissions in emerging countries suggests they are in the early phase of economic growth, where industrial activities and emissions increase with GDP. In contrast, the insignificant relationship between GDP and CO_2 in developed countries indicates they may have reached a stage where economic growth no longer leads to higher emissions, aligning with the later phase of the EKC. This suggests emerging countries should engage in public-private partnerships for sustainable projects, implement environmental taxes, offer incentives like tax breaks for adopting energy-efficient technologies, and participate in international environmental agreements. These strategies signal a strong commitment to sustainability, attracting investments that support both economic growth and environmental protection.

For trade, the positive relationship between trade and N_2O emissions in emerging countries is likely due to increased agricultural activities and deforestation driven by trade demands. Previous studies have shown that trade drives deforestation, especially in emerging countries where increased agricultural exports reduce forest area. This suggests that emerging countries should invest in reforestation and afforestation to restore degraded lands, increase forest cover, offset emissions, and protect biodiversity. These initiatives mitigate the environmental impact of trade-driven agricultural activities and promote long-term sustainability.

For Manufacturing the findings indicate that the manufacturing sector does not have a substantial impact on CO_2 and N_2O emissions in both developed and emerging countries, challenging the traditional belief that industrial manufacturing is a primary driver of environmental degradation due to the exploitation of natural resources, this suggests that future research to explore these other potential contributors to emissions.

For political stability, these findings suggest that political stability in emerging countries increases CO_2 emissions. A stable political system can manage crises and adopt policies, but it alone is insufficient for sustainability. This supports the Pollution Haven Hypothesis, where economic growth in stable environments often prioritizes industry over the environment, leading to higher emissions. Therefore, stringent environmental regulations and comprehensive policies are essential to balance growth and sustainability.

For urbanization the findings suggest that uneven economic growth in emerging countries leads to concentrated city activities and increased CO2 and N2O emissions. In developed countries, balanced growth means urbanization doesn't significantly affect CO2 emissions, though it does increase N2O emissions. Emerging countries should promote rural economic growth to reduce urban concentration and emissions. Both emerging and developed countries should strengthen urban planning with sustainable practices, like green spaces and efficient public transportation, to reduce urbanization-related emissions.

For Population growth the findings to reducing both CO2 and N2O emissions in emerging countries, and only N2O emissions in developed nations. This trend suggests that increasing populations may foster greater environmental consciousness and lead to more sustainable practices. This suggests prioritizing the formulation of integrated policies to maintain awareness and promote more environmentally friendly.

The model of N2O emissions demonstrates a relatively high explanatory power particularly in emerging countries, indicating that it captures a substantial part of the variability in emissions, suggesting stricter environmental regulations should be implemented to address this sensitivity. This includes setting higher standards for industrial emissions, enforcing compliance through regular inspections and penalties, and incentives like tax breaks and subsidies used to promote the adoption of cleaner technologies, strengthening environmental governance by enhancing the capacities of regulatory bodies and fostering collaboration between government agencies, industries, and civil society will ensure effective implementation and monitoring of these policies.

The current CO2 models in both emerging and developed countries fail to adequately account for emissions variability. Improving the models for CO2 and N2O emissions in developed countries is essential for advancing future research. Such enhancements provide more precise insights for policymakers.

The difference results from the previous study because this research covers 131 countries and is divided into two groups, developed and emerging countries. This division contributes to the variability in the model outcomes, underscoring the need for tailored approaches in future studies to better capture the unique characteristics and factors influencing emissions in these different groups.

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