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CO_2 Emissions and Macroeconomic Indicators in Emerging Market Countries

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Abstract. The increasing economic growth in emerging market countries has led to rising concerns about environmental sustainability, particularly CO2 emissions. This study aims to analyze the effect of GDP per capita, Foreign Direct Investment (FDI), and Government Expenditure on CO2 emissions in five emerging economies (Indonesia, India, China, Russia, and Brazil) during the 1998–2022 period using panel data analysis techniques. By applying the Chow and Hausman tests, the Fixed Effect Model (FEM) is identified as the best model for this study. The findings indicate that GDP per capita positively and significantly influences CO2 emissions, supporting the Environmental Kuznets Curve (EKC) hypothesis. Conversely, FDI has a negative and significant effect, aligning with the Pollution Halo Hypothesis, as foreign investments introduce environmentally friendly technologies. Similarly, Government Expenditure negatively and significantly influences CO2 emissions, highlighting the role of public spending in promoting sustainable infrastructure and reducing emissions. These findings suggest that sustainable economic growth, increased public spending on green projects, and incentivizing environmentally friendly FDI are essential for balancing economic growth and environmental sustainability in emerging economies.

Keywords: CO_2 Emissions, GDP per Capita, Foreign Direct Investment, Government Expenditure

JEL Codes: O44, P18, Q56

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1. Introduction

Environmental degradation, particularly to global warming, is a significant challenge driven by greenhouse gas (GHG) emissions such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Although CO_2 has a lower heat absorption capacity compared to CH4 and N2O, it accounts for 74% of total global GHG emissions, which reached 32,553.48 $MtCO_2$ (Kweku et al., 2018; Tang, 2017). The rise in CO_2 emissions is primarily the result of rapid economic activities, particularly in countries undergoing industrialization and experiencing increased energy consumption alongside economic growth (World Bank, 2016). Data from the International Energy Agency (2023) shows that CO_2 emissions have steadily increased from 23.4 $MtCO_2$ in 1998 to over 36.8 $MtCO_2$ in 2022, with projections indicating further increases. This trend poses a significant threat to both ecosystem stability and the global economy in the long term, as extreme weather events continue to rise, leading to substantial economic losses (Annur, 2022).

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Environment quality issues are not only a challenge for developed countries but also for emerging economies undergoing industrialization, such as Indonesia, India, and China. The rapid economic growth in these countries is often accompanied by increased CO_2 emissions, further exacerbating global environmental problems (Todaro et al., 2009). Sectors that rely on natural resources, such as agriculture and tourism, are particularly vulnerable to environmental degradation, which could reduce income and employment opportunities (Medrilzam, 2021). Therefore, sustainable economic development is critical, where economic growth must be accompanied by efforts to reduce CO_2 emissions and ensure environmental sustainability.

Considering this global phenomenon, Table 1 below presents data on CO_2 emissions from the world's largest emitters. China, the leading contributor with 11,397 $MtCO_2$, plays a dominant role in the issue, with emissions nearly twice those of the United States, which ranks second with 5,057 $MtCO_2$. Other major contributors, such as India (2,830 $MtCO_2$), Russia (1,652 MtCO2), and Japan (1,054 $MtCO_2$), also have significant shares of global emissions. Indonesia, with emissions of 729 $MtCO_2$ in the sixth rank, highlighting the importance of considering the role of developing countries in the global context.

Table 1. Countries with the Highest CO2 Emissions in 2022

Ranking	Countries	Total Emissions (MtCO2)
1	China	11397
2	USA	5057
3	India	2830
4	Russia	1652
5	Japan	1054
6	Indonesia	729
7	Iran	691
8	Germany	666
9	Saudi Arabia	663
10	South Korea	601
11	Canada	548
12	Mexico	512
13	Brazil	484
14	Turkey	436
15	South Afrika	404

Source: Global Carbon Atlas (2024)

As of 2023, China, the United States, and India are the top three contributors to global energy-related pollution, together accounting for over 53% of global emissions (IEA, 2023). Among these, China and India are emerging market economies playing a pivotal role as the largest contributors to global emissions. According to MSCI (Morgan Stanley Capital International) in the Emerging Market Index, countries such as China, India, Indonesia, Brazil, Malaysia, Russia, Turkey, and 17 others across Asia, Europe, the Middle East,

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Latin America, and Africa are classified as emerging markets. These economies are marked by rapid economic growth, industrialization, and modernization, often accompanied by a growing middle class and relatively young populations (Hartono, 2014). The rapid development and heavy reliance on fossil fuels for industrialization and urbanization in these countries significantly contribute to the global emissions crisis.

Figure 1 presents per capita emissions from five emerging market countries (Indonesia, India, China, Russia, Brazil), showing the annual amount of carbon dioxide (CO_2) produced annually by individuals in these countries. It also highlights patterns in energy consumption and production that influence carbon emissions.

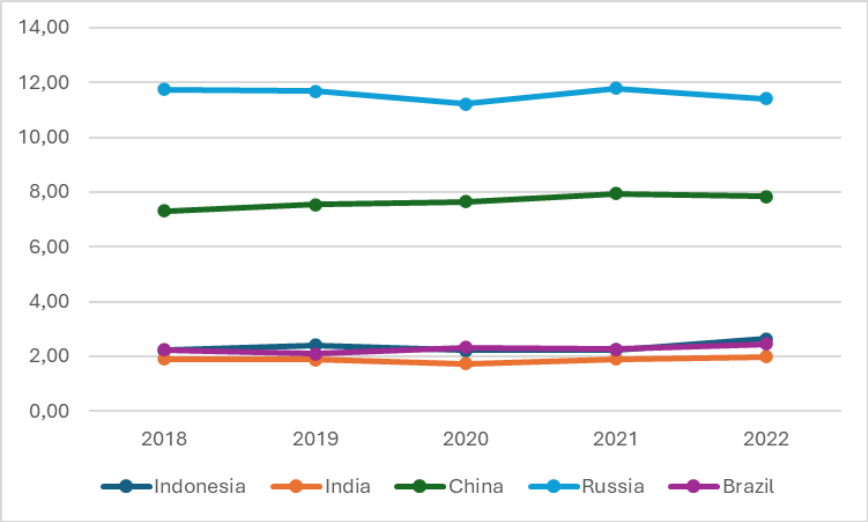

Figure 1. Per Capita CO_2 Carbon Emissions of 5 Emerging Market Countries
Source: Our World in Data (2024)

Between 2018 and 2022, per capita carbon emissions in emerging market countries exhibited significant variations in growth rates. Russia recorded the highest emissions, starting at 11.75 $MtCO_2$ in 2018 and slightly decreasing to 11.41 $MtCO_2$ in 2022. In comparison, China, despite being a major industrial player, had lower emissions, with 7.83 $MtCO_2$ in 2022, following a peak of 7.95 $MtCO_2$ in 2021. Meanwhile, India showed a more modest increase, rising from 1.89 $MtCO_2$ in 2018 to 1.99 $MtCO_2$ in 2022, reflecting slower growth in energy consumption compared to the other countries.

The rise in carbon emissions can be attributed to several factors, with economic development playing a key role. This includes government spending, foreign investment, and international trade (Arifah, 2023). Economic growth focused on improving public welfare often coincides with rapid development, serving as an indicator of national progress (Jonaidi, 2014). However, industrial and transportation activities have a significant impact on air and water quality, contributing to environmental degradation and increasing CO_2 emissions (Putri, 2023; Rahman, 2020; Shahbaz et al., 2017).

Furthermore, rising energy consumption, especially in fast-growing economies, exacerbates carbon emissions. The heavy reliance on fossil fuels for energy needs is a key driver. Tsandra et al. (2023) argue

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that rapid economic growth, coupled with energy-intensive consumption, directly leads to higher carbon emissions in these countries. This highlights the need for increased attention to environmental impacts, even as countries continue to develop.

A country's development is typically assessed using indicators like national income, with GDP per capita being one of the primary metrics (Nadeak & Nasrudin, 2023). Aggregate economic growth is also measured by GDP, and comparisons of GDP per capita between countries provide valuable insights into their economic conditions (Rachmawati et al., 2022).

Besides GDP per capita, foreign direct investment (FDI) is also important in driving economic growth by increasing market opportunities and attracting more investors. FDI stimulates capital formation, creates jobs, and introduces advanced technologies that enhance a country's economic competitiveness (Behname, 2012; Patricia et al., 2013). Rising national and household incomes further drive demand for goods and services, strengthening the economy and attracting more investment (Alfiyahnur et al., 2023)

However, FDI also has controversial environmental effects. Some studies suggest that FDI can increase carbon emissions, as it often supports energy-intensive industrial activities (Demena & Afesorgbor, 2020). On the other hand, FDI can also encourage the development of stronger environmental policies that help mitigate negative environmental impacts (Abdouli & Hammami, 2017).

Government spending can also stimulate economic activity, including in energy-intensive industries, which may contribute to CO_2 emissions. Additionally, government revenues, often tied to the energy sector, can have an environmental impact (Ramlogan & Nelson, 2024). The relationship between government spending and environmental outcomes has been theoretically explored by scholars (Dodds et al., 2010; G. Halkos & Paizanos, 2013). Four main effects describe how government spending can influence environmental quality: scale, composition, technique, and income.

Economic growth tends to put more pressure on the environment, as suggested by the scale effect, while the composition effect highlights how human activities over time can damage environmental quality. The technique effect suggests that improvements in labor productivity might lead to more demand for government investment in environmental sectors. Lastly, the income effect indicates that as income levels rise, people become more aware of environmental issues and push for more government spending on environmental programs.

In the context of growing global economic integration and the increasing challenges faced by emerging market countries in balancing economic growth with environmental sustainability, this study aims to analyze the impact of GDP per capita, Foreign Direct Investment, and Government Expenditure on CO_2 emissions in Emerging Market Countries in 1998-2022.

2. Literature Review

Many studies have examined the relationship between economic growth, foreign direct investment (FDI), and CO_2 emissions, revealing significant interactions among these factors. Research by Ainiasa & Bashir (2023); Prasetyani et al. (2021) suggest that GDP per capita and FDI have a positive impact on CO_2 emissions in Indonesia. Increased economic activity and foreign investment often lead to the intensive exploitation of natural resources, which in turn raises CO_2 emissions. On the other hand, government spending has a negative impact on emissions, although it has not yet been effective in mitigating emission

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fluctuations. A study by Pertiwi et al. (2024) also shows a positive correlation between GDP and CO_2 emissions, indicating that higher economic output tends to result in a greater environmental impact.

At the same time, the relationship between FDI and CO_2 emissions has been a key focus of international studies. In the BRICS countries, research by Hassan et al. (2024) that while GDP per capita positively affects CO_2 emissions, FDI and government spending have a negative effect. This suggests that foreign investments can promote the adoption of green technologies and energy efficiency, helping to reduce emissions. FDI in developing countries often brings environmentally friendly technologies, especially when supported by good governance. Other studies, such as those by Khalid et al. (2024); Rizki & Anggraeni (2022); Tahir et al. (2023); Yi et al. (2023), support this finding, showing that FDI significantly reduces CO_2 emissions by improving energy efficiency and implementing stricter environmental standards.

However, research by He et al. (2020) on the BRICS countries reveals that FDI is positively related to trade and CO_2 emissions, suggesting that while FDI can bring environmentally friendly technology, it can also lead to higher emissions in countries with greater trade activity. This highlights the importance of the economic context and regulations in determining FDI's impact on emissions. Huay et al. (2022); and Yanting et al. (2022) further explain that the effect of FDI on CO_2 emissions can be more significant in countries facing structural challenges, such as corruption or weak regulatory frameworks, which hinder the effective implementation of green technologies. In contrast, Pratama & Panjawa (2022) found no significant effect of FDI and energy on CO_2 emissions, whether in the short or long term, although economic growth showed a small, positive, but insignificant impact.

In addition to GDP per capita and FDI, government spending is frequently cited as a crucial factor in controlling CO_2 emissions. Several studies show varying effects of government spending on CO_2 emissions. Basri et al. (2019) found that while GDP per capita and FDI positively affect CO_2 emissions, trade openness tends to reduce emissions. Conversely, government spending in environmental sectors remains relatively low, as shown by Azwardi et al. (2022), who found a significant negative impact on environmental degradation. While government spending can lead to increased CO_2 emissions, Saud et al. (2019) noted that financial development can help reduce those emissions. Research by Nguyen (2024) supports the view that government spending contributes to lowering CO_2 emissions, although indirectly, government expenditure on economic growth, as shown by Oh (2023), can increase emissions through higher growth rates.

Further research by Cheng et al. (2021) highlights the importance of government spending on education and infrastructure in the context of reducing CO_2 emissions. Cheng et al. (2022) argue that spending on education plays a role in reducing emissions, while spending on infrastructure can slow down the process of emission reduction. Additionally, Halkos & Paizanos (2013) found that higher-income countries generally have stricter environmental regulations. Therefore, reducing government spending in these countries can improve environmental quality, including reducing CO_2 emissions. In this regard, clean fiscal policies are necessary to reduce CO_2 emissions more effectively, particularly in cities with similar socio-economic conditions. Halkos et al. (2014) concluded that while government spending can reduce local pollution, more strategic and coordinated policies are required to decrease global CO_2 emissions.

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3. Methodology and Data

This study examines the impact of GDP per capita, Foreign Direct Investment (FDI), and government expenditure on CO_2 emissions in five emerging market countries. The data used in this research is secondary data, meaning it was previously collected and published by data-gathering institutions (Kuncoro, 2018). The secondary data sources include the World Bank's World Development Indicators and Our World in Data for 1998-2022. The selected emerging markets are those with the highest carbon emissions globally, as identified by the Global Carbon Atlas. These countries are: (1) Indonesia, (2) India, (3) China, (4) Russia, and (5) Brazil.

The study uses both quantitative and descriptive analysis methods. According to Kuncoro (2018), descriptive analysis aims to explain research variable data typically presented in tables or graphs and connect it to relevant theories. On the other hand, quantitative analysis employs mathematical, statistical, and econometric approaches to identify the relationships between the independent variables GDP per capita, Foreign Direct Investment, and Government Expenditure and the dependent variable CO_2 emissions.

The data analysis technique employs panel data. The three models used are the Common Effect Model, Fixed Effect Model, and Random Effect Model. These models are selected based on assumptions regarding the relationship between the error components and the independent variables (regressors) in the research model. The advantages of panel data regression models are: (i) increasing the amount of data by combining time and cross-sectional dimensions, (ii) minimizing bias in estimation, (iii) allowing for a more dynamic explanation of variable behavior, and (iv) avoiding multicollinearity. Consequently, the panel data regression method does not use the Ordinary Least Squares (OLS) method and does not require testing for violations of classical assumption tests (Asngari, 2020).

$$CO_2 = F\ (GDP, FDI, GE) \quad (1)$$

Then a regression equation is constructed, as represented in equation (2):

$$CO_2it = \beta 0 + \beta 1\ LnGDPit + \beta 2\ FDIit + \beta 3\ LnGEit + eit \quad (2)$$

Description:

β0 = Parameter Intersep

CO_2 = Carbon Dioxide Emissions

GDP = GDP per Capita

FDI = Foreign Direct Investment

GE = Government Expenditure

β1-β3 = Regression Coefficient of Each Independent Variable

t = Time Period

i = Observation District/City

eit = Error term

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4. Empirical Result

4.1 Model Estimation Result

This model provides an explanation and a concise summary of real-world phenomena (Gujarati, 2004). The independent variables considered in this study include GDP per capita, FDI, and Government Expenditure, while CO_2 Emissions serve as the dependent variable. Panel data regression will be used to estimate the model, employing Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM) to determine the best-fitting model. The statistical estimation model is outlined as follows:

Table 2. Panel Data Estimation Results

Variable	Common Effect Model		Fixed Effect Model		Random Effect Model	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
C	-16.26046	0.0165	26.36456	0.0010	10.46507	0.0274
LnGDP	2.219679	0.0000	3.059049	0.0000	2.051606	0.0000
FDI	-0.527010	0.0193	-0.145846	0.0001	-0.167020	0.0000
LnGE	0.342926	0.6421	-4.117886	0.0002	-1.978105	0.0022

Source: Processed Data, EViews (2024)

The Common Effect Model (CEM), also known as the Constant Coefficient Model, assumes that the coefficients representing the impact of independent variables on the dependent variable remain constant across all cross-sectional units and periods. This implies no variation within the sample in the relationship between the dependent and independent variables. The primary limitation of this model lies in its inability to account for unique variances across specific cross-sectional units (Kuncoro, 2018). The Common Effect Model, or Pooled Least Squares (PLS), assumes that both the slope and intercept are constant across time and individuals. This approach is based on principles similar to those of the Ordinary Least Squares (OLS) method (Asngari, 2020). From the results of the panel regression analysis using CEM, the coefficients for the constant, GDP per capita, Foreign Direct Investment (FDI), and Government Expenditure on CO2 emissions were -16.26046, 2.219679, -0.527010, and 0.342926, respectively. The corresponding t-statistic values were -2.432687, 5.997061, -2.372008, and 0.465870, with p-values of 0.0165, 0.0000, 0.0193, and 0.6421. With a significance level (α) of 5% or 0.05, the analysis indicates that only GDP per capita has a significant impact on CO_2 emissions. The R-squared value is 0.346512, and the Adjusted R-squared is 0.330310, indicating that 33.03% of the variation in the dependent variable is explained by the three independent variables, while the remaining 66.97% is due to other factors. The panel regression model has an F-statistic of 21.38673, with a p-value of 0.0000, which confirms the overall significance of the model.

The Fixed Effects Model (FEM) assumes that differences across individuals (cross-sections) can be accommodated by differences in their intercepts. To estimate Fixed Effects and obtain individual-specific intercepts, the dummy variable technique is employed. This estimation approach is commonly referred to as the Least Squares Dummy Variable (LSDV) technique (Kuncoro, 2018). Through its panel regression system, EViews includes built-in features to estimate the Fixed Effects Model, eliminating the need to manually input dummy variables (Asngari, 2020). Based on Table 2, the panel regression results using the fixed effects model yielded coefficients for the constant (intercept), GDP per capita, FDI, and Government

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Expenditure on CO_2 emissions as 26.36456, 3.059049, -0.145846, and -4.117886, respectively. The corresponding t-statistics are 3.377628, 5.942558, -4.040553, and -3.878220, with p-values of 0.0010, 0.0000, 0.0001, and 0.0002. Since all independent variables have p-values below the significance level of α = 0.05, they are statistically significant in influencing the dependent variable. The R-squared value is 0.987740, and the Adjusted R-squared is 0.987007, suggesting that 98.77% of the variation in the dependent variable can be explained by the independent variables, with the remaining 1.23% influenced by other factors. The panel regression results also show an F-statistic of 1346.648, with a p-value of 0.0000, confirming the overall significance of the model.

The Random Effect Model (REM), also known as the error component model, assumes that variations in relationships across entities are random and explicitly captured within the residual errors. This model incorporates random errors associated with time, space, and other components that are stochastic within the regression framework, ensuring efficient and unbiased estimations. A key advantage of this model is that it does not require strict assumptions regarding variance. However, its main limitation lies in the need to accurately model the random errors (Kuncoro, 2018). According to Table 2, the results of the panel regression using the random effects model show the following coefficient values: 10.46507 for the constant, 2.051606 for GDP per capita, -0.167020 for Foreign Direct Investment (FDI), and -1.978105 for Government Expenditure on CO_2 emissions. The t-statistics corresponding to these values are 2.232203, 6.683630, -4.753639, and -3.130530, with p-values of 0.0274, 0.0000, 0.0000, and 0.0022. At a significance level of α = 0.05, GDP per capita and Foreign Direct Investment show statistically significant effects on CO_2 emissions. The R-squared value is 0.660954, and the adjusted R-squared is 0.652548, meaning that 65.25% of the variation in CO_2 emissions is explained by the independent variables, while the remaining 34.75% is due to other factors. Additionally, the F-statistic value of 78.62805, with a p-value of 0.0000, confirms the overall significance of the model.

4.2 Best Model Testing

In panel data regression, selecting the most appropriate model requires evaluating the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM) approaches. These methods are essential for analyzing the data and identifying the most suitable model for estimation. The process of choosing the right model includes performing several statistical tests, such as the Chow test, Hausman test, and Lagrange Multiplier test, to verify that the selected model provides the best fit for the data.

Table 3. Chow and Hausman Test

Effect Test	Statistics	df	Probability
Cross-section F	1529.896893	-4.117	0.0000
Cross-section Chi square	497.001814	4	0.0000
Cross-section Random	103.946275	3	0.0000

Source: Processed Data, EViews (2024)

The Chow test was used to compare the Common Effect and Fixed Effect models to identify which one was a better fit. The results indicated that the Fixed Effect model was the most appropriate for this study. This finding is confirmed by the F cross-section probability value in the CO_2 Emissions equation, which was

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0.0000, signifying that Prob F is less than 0.05. Furthermore, the Hausman test was performed to compare the Fixed Effect and Random Effect models to determine the better model for the CO_2 Emissions model (Asngari, 2020; N.Gujarati, 2004). The Probability (Prob.) Cross-section Random value from the Hausman test was 0.0000, indicating that the null hypothesis (H_0) was rejected. As a result, the Hausman test supports the use of the Fixed Effect Model (FEM) as the most suitable option for this study.

In this analysis, the Chow test was used to compare the Common Effect and Fixed Effect models, while the Hausman test was used to evaluate the Fixed Effect and Random Effect models. As a result, there was no need to conduct the Lagrange Multiplier (LM) test. The LM test is only necessary if the Chow test suggests that the Common Effect model is suitable, and the Hausman test recommends the Random Effect model. In such cases, the LM test helps determine whether the model should be a Common Effect or Random Effect. However, if both the Chow and Hausman tests confirm that the Fixed Effect model is the best option, the LM test is not required (Asngari, 2020; N.Gujarati, 2004).

From the Chow test results, the Fixed Effect model was identified as the best approach, as evidenced by an F probability value below 0.05, leading to the rejection of H_0 and acceptance of H_a. Similarly, the Hausman test confirmed the Fixed Effect model as the most appropriate, with a cross-section random probability value of 0.0000, which is also below 0.05, resulting in the rejection of H_0 and acceptance of H_a. Considering these findings, along with the fact that the number of periods (T) exceeds the number of cross-sectional units (N), the Fixed Effect model is determined to be the most suitable for this study. Table 4 below presents the estimation results based on the Fixed Effect model.

Table 4. Statistical Test Result Using the Fixed Effect Model Approach

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	26.36456	7.805644	3.377628	0.0010
LnGDP	3.059049	0.514770	5.942558	0.0000
FDI	-0.145846	0.036096	-4.040553	0.0001
LnGE	-4.117886	1.061798	-3.878220	0.0002
R-squared		0.987740		
Adjusted R-square		0.987007		
Prob(F-statistic)		0.000000		

Source: Processed Data, EViews (2024)

Before advancing to the next step of the analysis, various statistical tests were performed, including the F test, t-test, and coefficient of determination. The outcome of the F test showed that the probability value of the F statistic was below the 5% significance threshold (0.000 < 0.05), suggesting that the independent variables GDP per Capita, Foreign Direct Investment, and Government Expenditure collectively have a significant impact on CO_2 emissions. The t-test was then applied to examine the effects of each individual variable.

The probability value for the GDP per Capita variable, measured through government effectiveness, is below the 5% significance level (0.000 < 0.05), indicating that GDP per Capita has a significant impact on CO_2 emissions. Similarly, the probability value for the Foreign Direct Investment variable is also below the

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5% significance level (0.0001 < 0.05), suggesting that Foreign Direct Investment significantly influences CO_2 Emissions. For the Government Expenditure variable, the probability value is also below 0.05 (0.0002 < 0.05), confirming that Government Expenditure significantly affects CO_2 Emissions.

The panel data regression estimation using the Fixed Effect Model (FEM) shows that the constant value is 26.36456 with a positive sign, indicating that CO_2 emissions would increase by 26.36456 units if GDP per capita, Foreign Direct Investment (FDI), and Government Expenditure are held constant. Additionally, the coefficient for GDP per Capita (GDP) is 3.059049, meaning that a 1% increase in GDP per capita would lead to a 3.05% increase in CO_2 emissions in Indonesia, India, China, Russia, and Brazil. The coefficient for Foreign Direct Investment (FDI) is -0.145846, suggesting that a 1% increase in FDI would result in a 0.14% decrease in CO_2 emissions in these countries. Meanwhile, the coefficient for Government Expenditure is -4.117886, indicating that a 1% increase in government spending would lead to a 4.11% reduction in CO_2 emissions in Indonesia, India, China, Russia, and Brazil.

In this study, the coefficient of determination (R-squared) is 0.987740, or 98.77%. This means that the changes in the independent variables GDP per Capita, Foreign Direct Investment, and Government Expenditure explain 98.77% of the variation in the dependent variable, CO_2 Emissions. The remaining 1.23% is influenced by other factors.

The interpretation of the intercepts for each country can be seen in Table 5 as follows:

Table 5. Intercept Result

Negara	C	CI	C+CI
_INDONESIA--C	26.36456	-4.002212	22.362348
_INDIA--C	26.36456	-0.160748	26.203812
_CHINA--C	26.36456	3.609558	29.974118
_RUSIA--C	26.36456	4.300256	30.664816
_BRASIL--C	26.36456	-3.746855	22.617705

Source: Processed Data, EViews (2024)

Based on the model equation for Indonesia, it can be concluded that all independent variables, namely GDP per Capita, Foreign Direct Investment (FDI), and Government Expenditure, have a significant impact on CO_2 emissions. Indonesia has an intercept value or individual effect of -4.002212, which is negative. This means that if GDP per Capita, FDI, and Government Expenditure are at their lowest or held constant, CO_2 emissions in Indonesia will decrease by 4.00, resulting in a CO_2 emission value of 22.362348. Another country with a negative intercept is India, with a value of -0.160748. This indicates that if GDP per Capita, FDI, and Government Expenditure are at their lowest or constant, CO_2 emissions in India will decrease by 0.16, resulting in a CO_2 emission value of 26.203812. Brazil also has a negative intercept of -3.746855, meaning that CO_2 emissions in Brazil will decrease by 3.74, resulting in a CO_2 emission value of 22.617705.

Meanwhile, China and Russia, as the largest contributors to per capita emissions globally, have positive intercept values. China has an intercept value of 3.609558, meaning that if GDP per Capita, FDI, and Government Expenditure are at their lowest or constant, CO_2 emissions in China will increase by 3.60, resulting in a CO_2 emission value of 29.974118. Russia has an intercept value of 4.300256, meaning that if

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GDP per Capita, FDI, and Government Expenditure are at their lowest or constant, CO_2 emissions in Russia will increase by 4.30, resulting in a CO_2 emission value of 30.664816.

The Role of GDP per Capita in CO_2 Emission

The panel data estimation using the Fixed Effect Model in this study concludes that GDP per capita, in isolation, has a positive and significant impact on CO_2 emissions in five emerging market countries (Indonesia, India, China, Russia, and Brazil) from 1998 to 2022. The coefficient for GDP per capita is 3.059049, with a positive sign. This indicates that any increase in GDP per capita in these countries will be followed by an increase in carbon dioxide emissions. Specifically, a 1% rise in GDP per capita will lead to a 3.05% increase in CO_2 emissions in these five countries.

An increase in GDP per capita is often associated with heightened economic activity, which in turn affects CO_2 emissions. As a measure of economic growth, GDP per capita reflects a country's capacity to produce goods and services, typically accompanied by greater energy consumption. Rapid economic growth, particularly in sectors that are heavily dependent on energy, such as industry, transportation, and construction, leads to a higher demand for energy. However, this rise in energy consumption is generally not matched by the adoption of environmentally friendly technologies, causing countries to continue relying on fossil fuels such as coal, oil, and natural gas (A. Hassan, 2020).

The dominant use of fossil fuels in industrial sectors, power generation, and transportation is a major source of carbon emissions (Gokmenoglu & Sadeghieh, 2019; Pertiwi et al., 2024). According to data from WRI (2022), sectors that require high energy consumption, such as manufacturing and transportation, are responsible for approximately 60% of global CO_2 emissions. Meanwhile, the forestry and agriculture sectors contribute around 25% and 15%, respectively. In this regard, Hove et al. (2020) highlight that poorly managed economic development can lead to significant environmental damage, including pollution that harms ecosystems and degrades air quality.

Countries with high GDP per capita, such as Russia and China, demonstrate significant carbon emissions due to industrialization and reliance on fossil fuels. In Russia, GDP per capita rose from USD 1,834.86 in 1998 to USD 15,445.24 in 2022, with carbon emissions increasing from 9.92 to 11.41 metric tons per capita. Similarly, China's GDP per capita grew from USD 828.59 to USD 12,662.58, while emissions rose from 2.69 to 7.83 metric tons per capita during the same period.

Meanwhile, Brazil, Indonesia, and India, despite lower GDP per capita, also experienced notable emissions growth. Brazil's GDP per capita increased from USD 5,049.76 in 1998 to USD 9,065.50 in 2022, with emissions rising from 1.855 to 2.44 metric tons per capita, driven by deforestation and agriculture. In Indonesia, GDP per capita rose from USD 459.19 to USD 4,787.91, and emissions grew from 1.18 to 2.64 metric tons per capita, fueled by transport expansion, fossil energy use, and deforestation. India's GDP per capita increased from USD 412.51 to USD 2,366.31, with emissions rising from 0.85 to 1.99 metric tons per capita due to transport and coal dependency. Economic growth in these countries correlates with rising carbon emissions, driven by industrialization, fossil fuel dependence, and sectors like transportation and agriculture.

The findings of this study are consistent with the Environmental Kuznets Curve (EKC) theory, which suggests that, in the early stages of economic growth, increases in GDP per capita tend to exacerbate environmental degradation. During this phase, countries often prioritize accelerating economic growth by relying on energy-intensive industries and fossil fuels. Rapid economic growth in sectors such as industry,

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transportation, and power generation significantly contributes to increased energy consumption, and, consequently, higher carbon emissions. While there is potential for transitioning to environmentally friendly technologies in the future, countries in the early stages of economic growth are generally not yet focused on environmental policies or energy-efficient technologies (Ainiasa & Bashir, 2023; Özokcu, S., & Özdemir, 2017).

The results of this study align with several previous studies by Ainiasa & Bashir (2023); Bashir et al. (2021); Basri et al. (2019); Hassan (2020); Marwa et al. (2022); Pertiwi et al. (2024); Poetri et al. (2023); Prasetyani et al. (2021); Pratiwi et al. (2024); Rizki & Anggraeni (2022); Wijaya et al. (2021); Zaekhan & Nachrowi (2015), all of which indicate that GDP per capita has a positive and significant impact on carbon dioxide emissions. This means that as GDP per capita in a country increases, CO2 emissions in that country will also rise.

The Role of Foreign Direct Investment in CO_2 emission

In the context of global economic development, Foreign Direct Investment (FDI) is also considered a key driver of economic growth, a source of employment, and a channel for technology transfer, which can enhance productivity in developing countries (Demena & van Bergeijk, 2019; Sapkota & Bastola, 2017). However, the impact of FDI on the environment can have two contrasting effects. On one hand, FDI has the potential to increase carbon emissions, especially when incoming investments focus on pollution-intensive industries. On the other hand, FDI can also have a positive environmental impact, such as through the transfer of greener technologies (Iršová & Havránek, 2013).

The panel data estimation using the Fixed Effect Model in this study reveals that, on a partial basis, Foreign Direct Investment has a negative and significant impact on CO_2 emissions in five Emerging Market countries (Indonesia, India, China, Russia, and Brazil) from 1998 to 2022. The coefficient value of the Foreign Direct Investment variable is -0.145846 with a negative sign. This means that each increase in Foreign Direct Investment in these countries will be followed by a reduction in carbon dioxide emissions. Specifically, a 1 percent increase in foreign direct investment will result in a 0.14 percent decrease in CO2 emissions across these five Emerging Market countries.

Foreign direct investment (FDI) in the countries analyzed has fluctuated significantly over time, shaped by factors such as government policies and industrial priorities. In China, FDI declined from 4.44% in 1998 to 1.06% in 2022. However, the renewable energy sector benefited from this investment, with companies like Goldwind and Sinovel Wind utilizing FDI to develop advanced wind turbine technology. This contributed to a slight reduction in carbon emissions, which fell from 7.23 metric tons in 2013 to 7.09 metric tons in 2017, demonstrating that progress in green energy continued despite reduced FDI, though its impact remained limited. Similarly, in India, FDI remained relatively stable, ranging between 0.47% and 1.49% from 1999 to 2022. Companies such as Suzlon Energy and Tata BP Solar used FDI to advance renewable energy technologies, including wind and solar power plants, helping stabilize carbon emissions between 1.89 and 1.99 metric tons. While the effect of FDI on carbon emission reductions is more constrained in some cases, it underscores the role of foreign investment in supporting green energy initiatives and technologies. Nonetheless, external factors also significantly influence overall emission trends (Lema & Lema, 2012).

This phenomenon supports the Pollution Halo Hypothesis, which suggests that FDI brings advanced technologies and more efficient equipment that conserve resources and have a positive impact on

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environmental quality. Incoming FDI not only boosts economic sectors but also introduces technologies that help reduce carbon emissions. In this context, the FDI received by these countries contributes to improving environmental quality through more environmentally friendly methods.

The technology brought by FDI, particularly in the form of sustainable and environmentally friendly innovations, plays a crucial role in mitigating the negative environmental impact. Previous studies, such as those by Iršová & Havránek (2013), have shown that the technology gap between developed and developing countries influences the impact of FDI on the environment. When FDI brings green technology that can be adopted by domestic companies, it leads to a reduction in carbon emissions. This has been the case in the countries studied in this research, where more efficient green technologies have been implemented, bringing positive effects on the environment.

FDI that focuses on green innovation, will provide long-term benefits for the host countries. Developing countries, as covered in this study, are increasingly aware of the importance of directing FDI flows towards more environmentally friendly sectors. This green innovation not only helps reduce pollution but also fosters the creation of more sustainable industries. Multinational companies operating in developing countries tend to bring more environmentally friendly technologies than domestic companies. This is because foreign companies are required to comply with stricter environmental standards in their home countries, which in turn encourages them to bring cleaner production technologies to host countries (Demena & Afesorgbor, 2020)

Research by Eskeland & Harrison (2003) shows that U.S.-based companies operating in developing countries tend to implement environmentally friendly practices and use clean energy in their production processes. Previous studies that also support the findings of this research, such as those by Adedoyin et al. (2022); Khalid et al. (2024); Rizki & Anggraeni (2022); Yi et al. (2023); Zhu et al. (2016) have shown that Foreign Direct Investment can have a negative impact on carbon dioxide emissions. While FDI is often associated with increased pollution in some countries, in countries with strict environmental regulations and green technologies, FDI can accelerate the transition to a low-carbon economy. Therefore, while there is a view that FDI may increase pollution in some countries with weak regulations, much research indicates that FDI can be a significant driver of environmental sustainability, particularly by introducing more efficient green technologies and environmentally friendly practices.

The Role of Government Expenditure in CO_2 emission

Government expenditure plays an important role in influencing carbon emissions, as shown by various theories and studies. Halkos & Paizanos (2013) explain the link between government spending and environmental quality through four effects: scale, composition, technique, and income. The scale effect suggests that rapid economic growth increases environmental pressures, leading to higher government spending to address these challenges. The composition and technique effects focus on how human activities and improvements in productivity create a greater need for public investment in environmental efforts. Finally, the income effect shows that as income rises, people become more concerned about environmental quality, which in turn boosts demand for government spending in this area.

This study supports these assertions by demonstrating that government expenditure has a significantly negative impact on CO_2 emissions in five emerging market countries (Indonesia, India, China, Russia, and Brazil) during the 1998–2022 period. The coefficient for government expenditure is -4.117886, indicating that a 1% increase in government spending reduces CO_2 emissions by 4.11% in these nations. The

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government expenditure data used in this study refers to final government consumption, allocated to mitigating externalities such as carbon dioxide emissions.

In the early stages of economic growth, government spending on infrastructure investments, such as the development of electricity grids and roads, may lead to increased energy consumption and higher emissions (Zhang et al., 2021). However, when allocated to sustainability sectors, government expenditure can generate positive environmental impacts. Public spending targeted at renewable energy and managed with good governance reduces reliance on fossil fuels, which are the primary contributors to carbon emissions (Nguyen, 2024).

Government expenditure is closely linked to economic growth and environmental quality. Theoretically, public spending drives economic growth as it constitutes a key component of GDP, alongside consumption, investment, and net exports. The relationship between economic growth and environmental quality is explained by the Environmental Kuznets Curve (EKC), which posits that in the early stages of economic development, carbon emissions and environmental degradation rise due to industrialization and fossil fuel use. During this phase, government expenditure is largely directed toward infrastructure development, such as roads and industrial facilities, to support economic growth. However, beyond a certain income threshold, environmental quality improves as nations prioritize sustainability policies, such as renewable energy and eco-friendly transportation. At this stage, government expenditure plays a pivotal role in allocating resources to environmental sectors, mitigating the negative impacts of rapid economic growth (Oh, 2023).

In China, the significant increase in government spending between 2010 and 2020, including allocations for sustainability programs, coincided with a slower growth rate in carbon emissions, decreasing from 7.23 metric tons in 2013 to 7.09 metric tons in 2017. This decline is linked to fiscal policies supporting energy transitions, reduced reliance on coal, and large investments in renewable energy like wind and solar, which helped restructure industries and lower emissions (Guan et al., 2018). A similar trend is seen in India, where government spending increased from USD 310 billion in 2020 to USD 353 billion in 2022, while carbon emissions stayed stable at around 1.89 - 1.99 metric tons. This stability suggests that fiscal policies aimed at promoting low-carbon sectors, especially in transportation and energy, are starting to make an impact. However, challenges like weak institutions and limited funding remain obstacles to achieving larger emission cuts (Dutta et al., 2016).

In Brazil, emissions fell from 2.74 metric tons in 2014 to 2.08 metric tons in 2019, while government spending remained consistent at around USD 380 - 420 billion. This decrease is tied to policies focused on reducing deforestation in the Amazon and supporting renewable energy. Initiatives like the REDD+ program successfully reduced deforestation by more than two-thirds (Boucher et al., 2013). While budgets were directed toward green economy projects and renewable energy development. Despite these achievements, limited resources and weak international policy influence still pose challenges to meeting emission goals (Firdausi et al., 2022). Meanwhile Russia, even though government spending dropped in 2020, carbon emissions remained steady at about 11 metric tons. This stability reflects the country's heavy dependence on fossil fuels, especially oil and gas, as the main contributors to its emissions (Kilinc-Ata & Likhachev, 2022). In Indonesia, higher government spending, which reached USD 102 billion in 2020, helped reduce carbon emissions from 2.41 metric tons in 2019 to 2.22 metric tons in 2020. Policies such as the REDD+ program to curb deforestation and green financing to encourage environmentally friendly practices (Pratama & Firmansyah, 2024) have shown positive results. Efforts to expand renewable energy and

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promote electric vehicles also aim to cut emissions further. However, issues with coordination and funding still present significant challenges.

The theory of government expenditure, as developed by Rostow and Musgrave, also highlights the relationship between public spending and the stages of economic development. In the initial stages, substantial government expenditure is allocated to investments in infrastructure, such as roads, healthcare, and education. As development progresses, the private sector assumes a more significant role, although governments continue to provide better-quality public goods and services. During this phase, industrial growth may contribute to increased air and water pollution. Consequently, governments must intervene with policies to mitigate these adverse effects, including reducing carbon emissions (Mangkoesoebroto, 2016).

The findings of this study align with global efforts under the Paris Agreement, which aims to limit global temperature increases to 1.5°C. Emerging economies such as China, India, Indonesia, Russia, and Brazil have committed to strengthening their environmental policies by increasing expenditures on clean technology, energy efficiency, and eco-friendly transportation. These measures reduce dependence on fossil fuels and contribute to lowering CO2 emissions.

This research is consistent with prior studies, such as those by Azwardi et al. (2022); G. E. Halkos & Paizanos (2012); Nguyen (2024); Oh (2023), which highlight that government expenditure can negatively influence CO_2 emissions by enhancing environmental quality through fiscal policies. These policies include pollution reduction initiatives, the adoption of environmentally friendly technologies, and heightened public awareness of environmental protection.

5. Conclusion and Recommendation

(1) GDP per Capita has a positive and significant impact on CO_2 emissions in five emerging economies (Indonesia, India, China, Russia, and Brazil). This finding illustrates that an increase in GDP per Capita tends to raise CO2 emissions in these countries. It aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that during the early stages of economic growth, industrialization and fossil fuel consumption typically rise, leading to higher emissions. This indicates that while per capita income grows, environmental pressure also increases due to heightened economic activities and energy consumption.

(2) Foreign Direct Investment (FDI) has a negative and significant effect on CO2 emissions in the five emerging economies (Indonesia, India, China, Russia, and Brazil). This result demonstrates that an increase in FDI tends to reduce CO_2 emissions in these countries, whereas a decline in FDI could lead to higher emissions. This is attributed to the transfer of environmentally friendly technologies and practices introduced by foreign companies. The findings support the Pollution Halo Hypothesis, which posits that foreign investments bring clean technologies and enhance energy efficiency, thereby helping to reduce emissions.

(3) Government Expenditure has a negative and significant influence on CO_2 emissions in the five emerging economies (Indonesia, India, China, Russia, and Brazil). The results suggest that increased government spending on environmental sectors, such as investments in renewable energy and sustainable infrastructure, can significantly lower CO_2 emissions in these countries. (4) The independent variables GDP per Capita, Foreign Direct Investment, and Government Expenditure collectively have a significant impact

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on the dependent variable, CO_2 emissions, in Indonesia, India, China, Russia, and Brazil over the 1998–2022 period.

Based on the discussion and conclusions presented, the policy implications that can be drawn from this study are:

(a) Governments must ensure that economic growth prioritizes sustainable sectors, such as renewable energy, eco-friendly agriculture, and green industries, rather than relying heavily on fossil fuel consumption. This shift is crucial to mitigate negative impacts on environmental quality.

(b) Public spending should focus on environmentally sustainable infrastructure projects, such as renewable energy-based public transportation, energy-efficient buildings, and effective waste and water management systems. Increased budget allocation for these areas is vital to reducing emissions and creating a cleaner, healthier environment for society.

(c) Policymakers should prioritize attracting foreign direct investment (FDI) that promotes environmentally friendly technologies. Incentives for FDI in renewable energy and green technology sectors can accelerate the adoption of clean technologies, enhance energy efficiency, and reduce CO2 emissions in the long term.

(d) Strengthening environmental regulations and implementing carbon tax policies is essential to support emission reduction efforts. Carbon taxes can incentivize industries to invest in cleaner technologies while reducing their environmental footprint, fostering a more sustainable economy.

(e) This study's limitations highlight the need for future research to adopt a broader model scope. The findings can serve as a valuable reference for policymakers aiming to design effective environmental and economic strategies.

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