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SIMULTANEOUS RELATIONSHIP ANALYSIS BETWEEN CARBON DIOXIDE EMISSIONS AND GDP PER CAPITA IN ASIA: THE DYNAMICS OF URBANIZATION, ENERGY CONSUMPTION, FOREIGN DIRECT INVESTMENT, AND TRADE OPENNESS

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Abstract
This study aims to analyze the simultaneous relationship between carbon dioxide (CO_2) emissions and GDP per capita in 10 Asian countries, considering the dynamics of urbanization, energy consumption, foreign direct investment (FDI), and trade openness. The research employs an explanatory quantitative approach using panel data covering the period 2000–2024, obtained from the World Bank (WDI). The analysis applies a simultaneous equation model estimated using the Two Stage Least Squares (2SLS) method to address endogeneity issues. The results indicate that CO_2 emissions are significantly influenced by GDP per capita, urbanization, energy consumption, FDI, and lagged emissions, highlighting the presence of persistence effects. Meanwhile, GDP per capita is significantly affected by CO_2 emissions, FDI, and its lagged value. These findings suggest that economic growth in Asia remains highly dependent on energy-intensive and investment-driven activities, characterized by strong path dependence. Overall, the relationship between economic growth and environmental degradation is found to be mutually interdependent within a simultaneous system.

Keywords: CO_2 Emissions, GDP Per Capita, Panel Data, 2SLS, Urbanization.

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INTRODUCTION

The increasing level of greenhouse gas emissions, particularly carbon dioxide (CO_2), has become a prominent global environmental issue within the sustainable development agenda (Kesaulya & Ikbal, 2024). CO_2 emissions primarily originate from economic activities related to production processes, energy consumption, and urban development (Kurdi, 2008). This condition places the relationship between economic growth and environmental degradation as a central focus in environmental economics studies, especially in Asia, a region known for its relatively high economic growth rate (Budianto & Kusumawardani, 2024).

Over the past five years, CO_2 emissions in Asia have shown an overall increasing trend. The decline observed in 2020 was temporary and driven by the contraction of economic activities due to the COVID-19 pandemic. As economic recovery progressed in 2021, emissions rose again, fueled by industrial expansion, increasing energy demand, and the continued dominance of fossil fuel use, particularly coal (IEA, 2021). Although several countries in the region have begun to slow or even reduce emissions through the development of renewable energy, these efforts have not been sufficient to curb the overall regional increase. Consequently, Asia remains a major contributor to global CO_2 emissions and faces significant challenges in achieving medium-term emission reduction targets (Petriella, 2025).

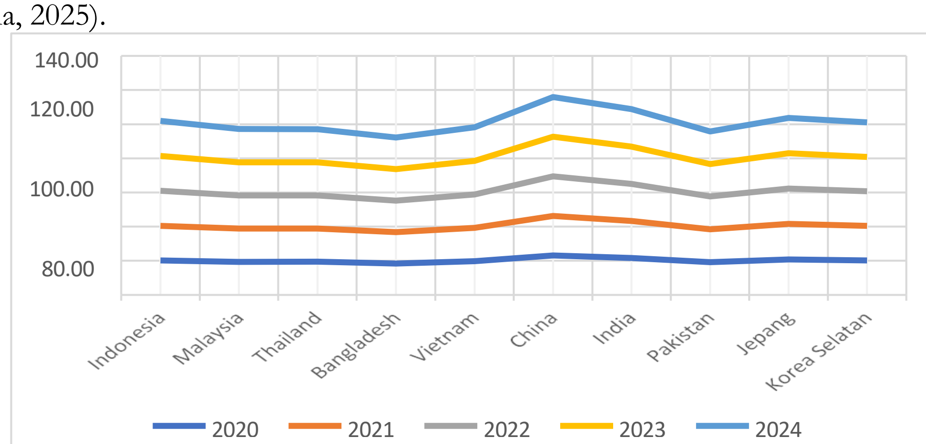

Figure 1.
Trends in Carbon Dioxide Emissions in 10 Asian Countries
Source: World Bank (processed data, 2026)

In line with these dynamics, over the past two decades, Asia has also undergone rapid economic transformation, reflected in rising GDP per capita, accelerated urbanization, and increasingly intensive global economic integration through foreign direct investment (FDI) and greater trade openness (IMF, 2025). These developments have not only improved welfare and expanded economic activities but have also increased energy demand and production intensity. This condition potentially intensifies ecological pressure, particularly through rising CO_2 emissions, highlighting a dilemma between accelerating economic growth and maintaining environmental sustainability in the region (Nguyen et al., 2025).

The relationship between economic development and environmental degradation can be conceptually analyzed using the IPAT framework (Impact, Population, Affluence, and

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Technology) and the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence, and Technology), which identify demographic factors, economic affluence, and technological use as primary drivers of environmental pressure. This study employs urbanization as an indicator of population structure changes, GDP per capita as a measure of affluence, and energy consumption as a proxy for technological activity with direct environmental implications. In addition to these domestic factors, economic globalization through FDI and trade openness also plays a significant role in influencing carbon emissions, both through changes in industrial structure, capital flows, and cross-country technology transfer.

However, a notable research gap remains insufficiently addressed. Most previous empirical studies (Zhang, 2021; Li, 2022; Wang et al., 2023) have examined the relationship between economic activity and carbon emissions using single-equation regression approaches, assuming a unidirectional causal relationship from GDP per capita to CO_2 emissions. Such approaches may overlook the possibility of bidirectional relationships, where rising emissions and environmental degradation can also affect economic performance through impacts on productivity, public health, and long-term sustainability. Furthermore, limited research has simultaneously integrated domestic factors such as urbanization and energy consumption with external factors such as FDI and trade openness within a single empirical framework capable of addressing endogeneity issues, particularly in the Asian context.

This study emphasizes the importance of applying a methodological approach capable of capturing the relationship between CO_2 emissions and GDP per capita more comprehensively. To achieve this, a panel data-based simultaneous equation model is employed, treating both CO_2 emissions and GDP per capita as endogenous variables. This approach enables the examination of bidirectional interactions between economic growth and environmental pressure while reducing potential bias arising from endogeneity. By incorporating urbanization and energy consumption as domestic factors, along with foreign direct investment and trade openness as external determinants, this study aims to provide a more comprehensive understanding of the dynamics between economic development and environmental degradation in Asia.

Therefore, this study is relevant in addressing existing research gaps by examining the simultaneous relationship between CO_2 emissions and GDP per capita while considering regional dynamics in Asia. The findings are expected to enrich empirical evidence in environmental economics literature, particularly through the integration of the STIRPAT framework with a simultaneous equation model, and to serve as a reference for formulating economic development policies aligned with environmental sustainability principles.

REVIEW OF LITERATURE

Trade Openness

Trade openness reflects the extent to which a country is integrated into the global economy through export and import activities (Rayadi, 2025). In international economic theory, free trade is considered an important factor that promotes economic growth,

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technological diffusion, and improved production efficiency across countries. However, from an environmental economics perspective, the impact of trade openness on carbon dioxide emissions is multidimensional and non-linear (Zhou et al., 2025).

Urbanization

Urbanization can be defined as a demographic transformation process characterized by an increasing proportion of the population living in urban areas relative to rural regions (Pacione, 2009). This process is part of structural economic development, marked by the concentration of economic, social, and infrastructural activities in urban centers. According to the United Nations (2018), urbanization occurs as a result of industrial and service sector expansion, economic modernization, and increasing employment opportunities in urban areas.

Energy Consumption

Energy consumption is one of the key determinants of carbon dioxide emissions, particularly in countries whose energy mix remains heavily dependent on fossil fuels such as coal, oil, and natural gas (Lismiyah et al., 2024). From an environmental economics perspective, energy use is inseparable from production activities, industrial processes, population mobility, and overall economic development dynamics. Rising energy consumption generally follows economic growth, accelerated urbanization, and industrial expansion, thereby simultaneously increasing environmental pressure (Myszczyszyn & Supron, 2022). Theoretically, energy demand is closely linked to income levels and the structural composition of an economy. Increases in GDP per capita drive higher energy use in households, transportation, and industrial sectors, which in turn directly contribute to higher carbon emissions. Empirical studies by Asngari et al. (2020) indicate that rising economic welfare leads to changes in household consumption patterns, which in the long term increase energy demand and production activity.

Environment and Sustainable Development

The concept of sustainable development emphasizes the balance between economic growth, environmental preservation, and social welfare. Development is not only measured by increases in GDP per capita, but also by a country's ability to maintain environmental quality for future generations (Stiglitz et al., 2009). Uncontrolled economic activities, such as fossil-fuel-based industrialization and rapid urbanization, may increase carbon dioxide emissions and exacerbate environmental degradation. Therefore, sustainable development requires the integration of economic objectives with environmental protection.

Externalities

The theory of externalities explains that economic activities may generate impacts on third parties that are not fully reflected in market prices. This occurs when economic activities produce social benefits or costs that are not internalized by economic agents, leading to inefficient resource allocation and potential market failure (Meade, 1973; Mankiw, 2020).

IPAT and STIRPAT Models

In environmental economics, the relationship between human activity and environmental pressure is commonly analyzed using the IPAT framework (Impact, Population, Affluence, Technology) and its extension, the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence, and Technology) (Ehrlich & Holdren, 1971;

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Dietz & Rosa, 1994). The IPAT model explains that environmental impact (I) is the result of the interaction between population size (P), affluence (A), and technology (T). Environmental impact is often represented by carbon dioxide emissions, while affluence is measured by income per capita, and technology reflects resource intensity in economic activities. Although conceptually useful, the IPAT model is deterministic and therefore less suitable for empirical analysis.

Environmental Kuznets Curve (EKC) Hypothesis

In the early stages of development, increases in GDP per capita are generally accompanied by higher energy consumption and intensive exploitation of natural resources. This condition leads to worsening environmental degradation as industrial expansion and urbanization intensify. The theory suggests that environmental pressure is a consequence of production structures and consumption patterns that are not yet ecologically efficient (Pigou, 1920). Empirical evidence in Asia suggests that the relationship between economic growth and carbon emissions remains positive in the early stages of development. A study by Azwardi et al. (2021) in Indonesia found that increased economic growth significantly drove up carbon emissions, reflecting the dependence of economic activity on high-carbon-intensive sectors and energy sources. This finding strengthens the relevance of the EKC hypothesis for developing countries in Asia.

RESEARCH METHOD

This study employs a quantitative approach with an explanatory research design using panel data to analyze the simultaneous relationship between CO_2 emissions and GDP per capita across ten Asian countries (Southeast Asia, South Asia, and East Asia) over the period 2000–2024. The study utilizes secondary data obtained from the World Bank's World Development Indicators (WDI), covering key variables such as CO_2 emissions and GDP per capita, along with supporting variables including urbanization, energy consumption, foreign direct investment (FDI), and trade openness. The analysis applies a simultaneous equation model using the Two Stage Least Squares (2SLS) method to address endogeneity issues and produce consistent parameter estimates. The use of panel data enables a more comprehensive analysis of cross-country and temporal dynamics, while proportional cluster sampling is employed to ensure regional representation and variability across Asian economies.

RESULTS AND DISCUSSION

Regression Results

Stationarity Test

Based on the testing results for 10 Asian countries with a total of 220–230 observations, all test methods yielded probability values of 0.0000, which are below the 5% significance level (0.05).

Table 1. Stationarity Test

Variabel	LLC	IPS	ADF	PP
statistic	-6.33132	-6.3866	84.5363	139.29
Probability	0.0000	0.0000	0.0000	0.0000

Source: EViews 12 output (processed data, 2026)

In the Levin, Lin & Chu (LLC) test, which assumes a common unit root process, a test statistic of -6.33132 with a probability value of 0.0000 was obtained. This result indicates that the null hypothesis of a unit root is rejected, meaning that the data are stationary.

Furthermore, the Im, Pesaran and Shin (IPS) test, which allows for an individual unit root process, also produced a statistic of -6.3866 with a probability of 0.0000. This indicates that, at the individual level, each country in the panel does not contain a unit root.

Similar results were obtained from the ADF-Fisher Chi-square test (84.5363) and the PP-Fisher Chi-square test (139.290), both of which also show probability values of 0.0000. Therefore, it can be concluded that the panel data used in this study are stationary at level form.

Cointegration Test

The results of the panel cointegration test using the Fisher method indicate that all null hypotheses are rejected at the 5% and 10% significance levels, as the probability values are below 0.05 or 0.10, based on both the trace test and the maximum eigenvalue test. This suggests the existence of at least one cointegrating relationship among the variables in the model.

Furthermore, the Kao test also shows a statistically significant result with a probability value of 0.0069, further confirming the presence of a long-run relationship among the variables. Thus, it can be concluded that the variables in this study are in long-run equilibrium, indicating that the model is not spurious and is suitable for further analysis.

Table 2. Cointegration Test

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	377.9	0.0000	202.6	0.0000
At most 1	208.5	0.0000	92.02	0.0000
At most 2	136.2	0.0000	70.16	0.0000
At most 3	86.46	0.0000	56.94	0.0000
At most 4	53.45	0.0001	39.71	0.0054
At most 5	40.25	0.0046	40.25	0.0046

Source: EViews 12 Output (processed data, 2026)

Goodness of Model Test

Simultaneity Test

The simultaneity test is conducted to examine whether the regression coefficients indicate that exogenous variables jointly have an influence on endogenous variables in each model.

Decision rules:

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a. H_0 is rejected if Prob. (t-statistic) < α (0.05)
b. H_1 is not rejected (accepted) if Prob. (t-statistic) > α (0.05)

Table 3. Simultaneity Test

Model	Variable	Coefficient	Std. Error	t-Statistic	Prob.
	C	4.27014	0.297076	14.37391	0.0000
	lnGDPpcF	-0.00186	0.000776	-2.396617	0.0174
	lnURB	-0.075712	0.027777	-2.725752	0.0069
lnCO2	lnENR	0.441668	0.039422	11.20357	0.0000
	lnCO2(-1)	0.646805	0.02862	22.59963	0.0000
	RESID_CO2	0.006591	0.001688	3.905484	0.0001
Model	**Variable**	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
	C	-0.538202	0.019451	27.66904	0.0000
	lnCO2F	0.061364	0.00123	49.89919	0.0000
lnGDPpc	FDI	0.013798	0.000202	68.35617	0.0000
	TO	-0.006102	5.28E-05	-115.543	0.0000
	lnENR	0.251846	0.003295	76.42716	0.0000
	lnGDPPC(-1)	0.761883	0.002482	306.9542	0.0000
	RESID_GDPpc	0.964944	0.008452	114.1617	0.0000

Source: EViews 12 Output (processed data, 2026)

The simultaneity test results indicate that the residual variables in both equations have probability values below 0.05, leading to the rejection of the null hypothesis. This implies the existence of simultaneity between the endogenous variables in the model, particularly between carbon dioxide emissions and GDP per capita. Therefore, the model is confirmed to be simultaneous in nature and requires estimation approaches such as Two-Stage Least Squares (2SLS) or Three-Stage Least Squares (3SLS) to obtain consistent and unbiased estimates.

Endogeneity Test in the Simultaneous Model

In simultaneous equation models, the presence of endogeneity is an important characteristic that must be tested, as it determines the appropriateness of the estimation method used. Conceptually, the null hypothesis (H_0) assumes that variables are exogenous (no endogeneity), while the alternative hypothesis (H_1) assumes that variables are endogenous. The decision rule is based on probability values, where H_0 is rejected if the probability is less than the 5% significance level (0.05), indicating the presence of endogeneity in the model.

Table 4. Endogeneity Test of Simultaneous Model

Model	Variable	F-statistik	Prob
	C		
	lnGDPpcF		

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lnCO2	lnURB lnENR lnCO2(-1)	42616.84	0.0000
	Variable	**F-satistik**	**Prob**
lnGDPpc	C lnCO2F FDI TO lnENR lnGDPpc(-1)	39978.88	0.0000

*Note: * = significant at 10 percent ** = significant at 5 percent *** = significant at 1 percent*

Source: EViews 12 output (processed data, 2026)

The endogeneity test results indicate that both equations produce highly significant F-statistics with probability values of 0.0000. This suggests that the variables in the model simultaneously influence the endogenous variables and that there is a bidirectional relationship within the system. Accordingly, it can be concluded that the model contains endogeneity. Therefore, estimation using the Ordinary Least Squares (OLS) method is no longer appropriate, and alternative approaches such as Two-Stage Least Squares (2SLS) or Three-Stage Least Squares (3SLS) are required to obtain consistent estimation results.

Simultaneous Model Estimation

Based on the model identification results using both the order condition and rank condition, it is found that both structural equations in this study fall into the over-identified category. This condition indicates that the number of available instrumental variables exceeds the number of endogenous variables being estimated, allowing the model to be consistently estimated. Consequently, the simultaneous model in this study is suitable to proceed to the parameter estimation stage using the Two-Stage Least Squares (2SLS) method. This approach is capable of addressing endogeneity problems and producing unbiased and consistent estimators.

F-Test Estimation Results of the ln_CO_2 Model

Table 5. F-Test of the ln_Co2 Model

Variable	Coefficient	F-statistic	Prob	R-Squared
C	1.382176			
lnCO2(-1)	0.866791			
lnGDPPC	-0.032579	6337.032	0.0000	0.998772
lnURB	0.117178			
lnENR	0.154319			
FDI	0.0199			

Source: EViews 12 Output (processed data, 2026)

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The results of the F-test for the lnCO_2 model show an F-statistic value of 6337.032 with a probability of 0.0000. The probability value, which is far below the 5% significance level (α = 0.05), indicates that the null hypothesis (H_0) is rejected. Therefore, it can be concluded that, simultaneously, all independent variables in the model—namely lnGDPPC, lnURB, lnENR, FDI, and lnCO_2(-1) have a significant effect on carbon dioxide emissions.

This finding indicates that the model has very strong explanatory power in explaining the variation of CO_2 emissions across 10 Asian countries. This is further supported by an R-squared value of 0.9987, implying that approximately 99.87% of the variation in CO_2 emissions is explained by the variables included in the model, while the remaining variation is explained by other factors outside the model.

In addition, the presence of the lagged variable lnCO_2(-1) with a high coefficient indicates a dynamic or persistence effect, meaning that past carbon emissions strongly influence current emission levels. Meanwhile, other variables such as GDP per capita, urbanization, energy consumption, and FDI jointly contribute to changes in carbon emissions, although their individual effects may vary.

Overall, these results demonstrate that the model is highly effective in explaining variations in carbon dioxide emissions and is supported by the significance of key explanatory variables. Accordingly, the lnCO_2 model is statistically significant in a simultaneous sense and is suitable for further analysis, both in examining structural relationships among variables and in formulating policy implications related to environmental sustainability and economic growth in Asia.

F-Test Estimation Results of the GDPpc Model

Table 6. F-Test of GDPpc Model

Variable	Coefficient	F-statistic	Prob	R-Squared
C	-17.12833			
lnCO2	1.032012			
FDI	-0.163137	4.63E+19	0.0000	0.986648
TO	0.071367			

Source: EViews 12 Output (processed data, 2026)

The results of the F-test for the lnGDPPC model show an F-statistic value of 4.63E+19 with a probability of 0.0000. The probability value, which is far below the 5% significance level (α = 0.05), indicates that the null hypothesis (H_0) is rejected. Therefore, it can be concluded that, simultaneously, the variables lnCO_2, FDI, and trade openness (TO) have a significant effect on GDP per capita across 10 Asian countries.

The extremely high F-statistic value reflects the strong explanatory power of the model in capturing the relationship between the independent variables and economic growth. This is further supported by an R-squared value of 0.986648, indicating that approximately 98.66% of the variation in GDP per capita is explained by the variables included in the model, while the remaining variation is attributable to factors outside the model.

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From an economic perspective, these results suggest that economic growth in Asia is not only influenced by internal factors such as production structure, but is also closely linked to environmental quality (CO_2 emissions) as well as external factors such as foreign direct investment and trade openness.

Hasil Estimasi Uji t Model ln_CO2

Table 7. Results of the t-test of the ln_CO2 Model

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.137979	0.063851	2.160962	0.0312***
C(2)	-0.024083	0.012705	-1.895499	0.0587**
C(3)	-9.98E-05	0.00014	-0.712947	0.4762
C(4)	0.013397	0.017796	0.752806	0.4520
C(5)	0.010666	0.003159	3.37623	0.0008***
C(6)	0.999621	0.004061	246.1571	0.0000***

*Note: * = significant at 10 percent ** = significant at 5 percent *** = significant at 1 percent*

Source: EViews 12 Output (processed data, 2026)

Based on table 4.8, the following structural equation is formed;

$$lnCO2 = 0.1379 - 0.0240*lnGDPpc - 9.9848*TO + 0.0133*lnENR +$$
$$(0.0638) \quad (0.0127)^{***} \quad (0.0001)^{***} \quad (0.0177)^{***}$$
$$0.0106*FDI + 0.9996*lnCO2(-1)$$
$$(0.0031)^{***} \quad (0.0040)^{***}$$

R^2 = 0.9986
DW = 1.7348

The model exhibits a very high coefficient of determination ($R^2 = 0.9986$), indicating that approximately 99.86% of the variation in carbon dioxide emissions can be explained by the variables included in the model. In addition, the Durbin–Watson statistic (DW = 1.7348) suggests that there is no serious autocorrelation problem within the model.

The results of the partial significance test (t-test) for the $lnCO_2$ model indicate that each variable has a different level of significance in influencing carbon dioxide emissions. The interpretation of each coefficient is as follows:

The constant term C(1) has a coefficient of 0.1379 and is significant at the 5% level (p = 0.0312). This indicates that when all independent variables are held constant, CO_2 emissions still maintain a positive baseline value, suggesting the presence of other unobserved factors influencing carbon emissions outside the model.

The lnGDPPC variable C(2) has a coefficient of -0.0240 with a probability value of 0.0587. Statistically, this variable is not significant at the 5% level but is significant at the 10% level. The negative coefficient indicates that an increase in GDP per capita tends to reduce CO_2 emissions, which may be interpreted as an early indication of the declining phase of the Environmental Kuznets Curve (EKC), although the effect remains relatively weak.

The trade openness variable C(3) has a coefficient of -9.9848 with a probability value of 0.4762, indicating that it is not statistically significant. This suggests that trade openness

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has not yet exerted a measurable effect on carbon emissions in the Asian region during the study period.

The energy consumption variable C(4) has a positive coefficient of 0.0133 with a probability value of 0.4520, indicating that it is not statistically significant. Although theoretically energy consumption is expected to increase carbon emissions, the results show that its effect is not statistically strong within the model.

The foreign direct investment (FDI) variable C(5) has a positive coefficient of 0.0106 and is significant at the 5% level (p = 0.0008). This indicates that an increase in FDI inflows contributes to higher CO_2 emissions. This finding is consistent with the pollution haven hypothesis, which suggests that investment tends to flow into countries with relatively weaker environmental regulations.

The lagged CO_2 emissions variable C(6) has a coefficient of 0.9996 with a probability of 0.0000, indicating very high statistical significance. The coefficient, which is close to one, reflects a very strong dynamic effect, where previous-period emissions strongly determine current emission levels (high persistence).

Overall, the t-test results indicate that the variables significantly affecting CO_2 emissions are GDP per capita (at the 10% significance level), FDI, and lagged CO_2 emissions, while trade openness and energy consumption do not show statistically significant partial effects. These findings suggest that carbon emission dynamics in Asia are more strongly driven by investment patterns and historical emission trends rather than trade and energy consumption in the short run.

GDPpc Model t-Test Estimation Results

Table 8. t-Test of GDPpc Model

	Coefficient	Std. Error	t-Statistic	Prob.
C(7)	-0.053526	0.023662	-2.262125	0.0242***
C(8)	0.008081	0.001296	6.236403	0.0000***
C(9)	-0.002284	0.006199	-0.368436	0.7127
C(10)	0.005589	0.001117	5.003023	0.0000***
C(11)	0.992153	0.004949	200.4724	0.0000***

*Note: * = significant at 10 percent ** = significant at 5 percent *** = significant at 1 percent*

Source: EViews 12 Output (processed data, 2026)

Based on table 4.1, the following structural equation is formed;

$$lnGDPPC = -0.0535 + 0.0080*lnCO2 - 0.0022*lnENR + 0.0055*FDI + 0.9921*lnGDPPC(-1)$$

(0.0236)*** (0.0012)*** (0.0061)*** (0.0011)*** (0.0049)***

R^2 = 0.9996

DW = 1.4625

The model demonstrates excellent performance, with a very high coefficient of determination (R^2 = 0.9996), indicating that approximately 99.96% of the variation in GDP

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per capita is explained by the variables included in the model. In addition, the Durbin–Watson statistic of 1.4625 suggests that there is no serious autocorrelation problem, although a relatively weak positive autocorrelation tendency may exist, which remains acceptable within a dynamic panel data framework.

The results of the partial significance test (t-test) for the lnGDPPC model can be interpreted as follows:

The constant term C(7) has a coefficient of -0.0535 with a probability value of 0.0242 (< 0.05), indicating statistical significance. The negative sign suggests that when all independent variables are held constant, there is a tendency for GDP per capita to decline, which may reflect the influence of omitted factors outside the model.

The carbon dioxide emissions variable C(8) has a positive coefficient of 0.0080 and is significant at the 1% level (p = 0.0000). This indicates that an increase in CO_2 emissions has a positive effect on GDP per capita. Economically, this finding implies that emission-generating economic activities—such as industrialization and energy consumption—remain key drivers of economic growth in the Asian region.

The energy consumption variable C(9) has a negative coefficient of -0.0022 with a probability value of 0.7127 (> 0.05), indicating that it is not statistically significant. This suggests that energy consumption does not have a direct and significant effect on GDP per capita within this model, although theoretically energy is an essential input in production processes.

The foreign direct investment (FDI) variable C(10) has a positive coefficient of 0.0055 and is significant at the 1% level (p = 0.0000). This indicates that increases in FDI contribute positively to GDP per capita growth. This finding is consistent with economic growth theory, which posits that foreign investment inflows enhance productive capacity, facilitate technology transfer, and improve economic efficiency.

The lagged GDP per capita variable lnGDPPC(-1) C(11) has a coefficient of 0.9921 with a probability value of 0.0000, indicating very high statistical significance. The coefficient, which is close to one, reflects strong persistence or dynamic effects, meaning that GDP per capita in the previous period strongly determines current economic conditions.

Overall, the t-test results show that the variables significantly affecting GDP per capita are CO_2 emissions, FDI, and lagged GDP per capita, while energy consumption is not statistically significant. These findings confirm that economic growth in Asia is still strongly driven by emission-intensive economic activities and foreign capital inflows, with a pronounced dynamic and path-dependent growth pattern over time.

CONCLUSION

1. Based on the results of the study, carbon dioxide emissions across 10 Asian countries are influenced by several key factors, namely GDP per capita, urbanization, energy consumption, and foreign direct investment (FDI). In general, CO_2 emissions exhibit an increasing trend in line with the intensity of economic activity, particularly in developing countries. The variables of foreign direct investment (FDI) and lagged emissions are found to have a positive and significant effect on CO_2 emissions, indicating the presence

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of persistence characteristics as well as the role of investment in driving energy-based industrial activities. Meanwhile, GDP per capita shows a weak negative effect, suggesting an initial indication of a shift toward more environmentally friendly growth patterns. Overall, carbon emissions in Asia still reflect an energy-intensive development model that is highly dependent on fossil fuels.

2. The results of the study indicate that GDP per capita is significantly influenced by carbon dioxide emissions, foreign direct investment (FDI), and its own lagged value. CO_2 emissions have a positive effect on GDP per capita, confirming that economic growth in Asia remains closely associated with emission-generating activities such as industrialization and energy consumption. FDI also contributes positively to GDP per capita by enhancing investment inflows, facilitating technology transfer, and improving economic productivity. In addition, the lagged GDP per capita variable exerts a strong influence, indicating that economic growth is dynamic and highly dependent on past conditions. Thus, economic growth in Asia continues to be dominated by an energy- and investment-based development model, characterized by a high degree of path dependence.

REFERENCES

Asngari, I., Suhel, S., Bashir, A., Arief, A. N. A., & Susanti, E. (2020). Rice Consumption Pattern of Rural Households in East OKU and South OKU Regencies South Sumatra Province Indonesia. *International Journal of Economics and Financial Issues*, *10*(1), 259–265. https://doi.org/10.32479/ijefi.9094

Azwardi, A., Sukanto, S., Igamo, A. M., & Kurniawan, A. (2021). Carbon Emissions , Economic Growth , Forest , Agricultural Land and Air Pollution in Indonesia. *International Journal of Energy Economics and Policy | Vol 11 • Issue 4 • 2021537 International Journal of Energy Economics and Policy*, *11*(4), 537–542. https://doi.org/10.32479/ijeep.11119

Budianto, M., & Kusumawardani, D. (2024). *The Impact of Institutional Quality on Carbon Dioxide Emission : A Case Study in Asia-Pasific Countries*. *5*(6), 4733–4752. https://doi.org/10.37385/ijedr.v4i6.6745

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of population growth. *Science*, *171*(3977), 1212–1217. http://links.jstor.org/sici?sici=0036-8075(19710326)3:171:3977%0A%3C1212:IOPG%3E2.0.CO;2-E

IEA. (2021). *global-energy-review-2021*. Licence: CC BY 4.0. https://doi.org/.iea.org/reports/global-energy-review-2021

Isbahi, M. B., Zuana, M. M. M., & Toha, M. (2024). The Multi-Social Relation of the Cattle Industry in the Plaosan Subdistrict Animal Market of Magetan Regency. *Malacca: Journal of Management and Business Development*, *1*(1), 31–46. https://doi.org/10.69965/malacca.v1i1.51

Janusz MyszczyszynBła˙zej Supron ´. (2022). Relationship among Economic Growth, Energy Consumption, CO 2 Emission, and Urbanization: An Econometric

Perspective Analysis. *Energies*, *15*(24), 9647. https://doi.org/https://doi.org/10.3390/en15249647

Kesaulya, I., & Ikbal, L. (2024). Emisi gas rumah kaca (CO 2 dan CH 4) pada kawasan mangrove di Pesisir Desa Poka , Kota Ambon. *JPLB*, *8*(1), 38–52. https://doi.org/10.36813/jplb.8.1.38-52

Kurdi, S. Z. (2008). Pengaruh emisi co2 dari Sektor Perumahan Perkotaan Terhadap Kualitas Lingkungan. *Jurnal Pemukiman*, *3*(2). https://doi.org/https://doi.org/10.31815/jp.2008.3.137-150

Lismiyah, E., Taher, A. R., Gunarto, T., & Aida, N. (2024). The Causality Between Energy Consumption and Carbon Emission in Indonesia. *Jurnal Riset Ilmu Ekonomi*, *4*(1), 27–38. https://doi.org/10.23969/jrie.v4i1.83

Meade, J. . (1973). *The Theory of Economic Externalities: The Control of Environmental Pollution and Similar Social Costs*. A. W. Sijthoff / Brill. https://doi.org/https://doi.org/10.1163/9789004634343_003

Nguyen, Q. K., Tran, D. L., Tran, X. H., Thanh, N., & Pham, N. (2025). *The complex relationship between carbon dioxide emissions , foreign direct investment , and economic growth in Asian countries. 6 (831).* https://doi.org/https://doi.org/10.1007/s43621-025-01730-8

Pacione, M. (2009). *Urban geography: A global perspective*. Routledge. https://doi.org/https://www.routledge.com/Urban-Geography-A-Global-Perspective/Pacione/p/book/9780415462013

Pigou, A. C. (1920). No Title. In *The Economics of Welfare*. Macmillan. https://www.econlib.org/library/NPDBooks/Pigou/pgEW.html

Rayadi, S. (2025). *The Influence of Market Size , Trade Openness , Inflation , And Financial Development on FDI in Indonesia*. *1*(1), 1–26. https://doi.org/10.51170/jmabr.v4i1.134

Stiglitz, J. E., Sen, A., & Fitoussi, J.-P. (2009). *Report by the Commission on the Measurement of Economic Performance andSocial Progress*. https://www.socioeco.org/bdf_fiche-document-2339_en.html

Yanita Petriella. (2025). *Asia Tenggara dan Asia Diprediksi Tak Capai Target Penurunan Emisi di 2030*. https://hijau.bisnis.com/read/20250506/651/1874769

Zhang, J. (2021). Environmental Kuznets Curve Hypothesis on CO 2 Emissions : Evidence for China. *Journal of Risk and Financial Management*, *14*(3), 93. https://doi.org/https://doi.org/10.3390/jrfm14030093

Zhou, R., Guan, S., & He, B. (2025). *The Impact of Trade Openness on Carbon Emissions : Empirical Evidence from Emerging Countries*. *18 (3)*(697), 1–20. https://doi.org/https://doi.org/10.3390/en18030697

Zhou, X., Fu, Y., Li, X., & Qiu, X. (2025). Structural bias of foreign direct investment and urban pollution emissions : exacerbating effects of competitive investment incentives. *Asia-Pacific Journal of Regional Science*, *9*(4), 1025–1051. https://doi.org/10.1007/s41685-025-00397-3