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Linking Macroeconomic Indicators To Carbon Emissions In ASEAN Emerging Economies: Empirical Evidence From Panel Data

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ABSTRACT

This study aims to examine the effect of gross domestic product, urbanization, foreign direct investment, and human development index on carbon dioxide (CO_2) emissions in five emerging ASEAN countries (Indonesia, Malaysia, Thailand, the Philippines, and Vietnam) during 2018–2023. The study uses a descriptive quantitative approach with multiple linear regression analysis. Model selection through Chow, Hausman, and Lagrange multiplier tests shows that the random effect model (REM) is the best. Data are sourced from Our World in Data and ASEAN Statistics. The results show that CO_2 emissions have an inverted U-shaped curve. Furthermore, GDP and FDI have a positive and significant effect on CO_2 emissions, indicating that economic activity and investment still depend on fossil fuels. Urbanization has a negative and significant effect, showing that good urban management can reduce emissions. Meanwhile, HDI has a negative but insignificant effect on CO_2.

INTRODUCTION

Increasing economic growth is the main goal in national development, where Gross Domestic Product (GDP) is often used as an indicator of achievement (Shahbaz, Raghutla, Chittedi, Jiao, & Vo, 2020). However, Choudhury, Kayani, Gul, Haider, & Ahmad (2023) stated that the acceleration of industrialization and economic activity encourages increased economic growth, which has consequences for the environment, especially carbon dioxide (CO2) emissions. These emissions are the main cause of global warming and climate change, which are triggered by greenhouse gases such as CO_2, CH_4, N_2O, and fluorine gas. The issue of energy and environmental sustainability is the main focus of the Sustainable Development Goals (SDGs), especially on goal 7 on clean and affordable energy, goal 11 on sustainable cities and settlements, and goal 13 on handling climate change. These three goals emphasize the importance of providing environmentally friendly energy, efficient and low-emission urban

governance, and mitigation efforts against increased CO_2 emissions to support sustainable economic growth.

According to Cozzi, Chen, & Kim (2023), 10% of the countries with the highest emissions come from the African and Asian regions, which are generally developing countries with high consumption levels and limited access to electricity and clean water. According to Todaro, the decline in environmental quality in the area is caused by pollution sourced from industrial activities, motor vehicles, and forest fires (Gupito & Kodoatie, 2013). The environment has a strategic role in the economic system, not only as a provider of facilities and raw materials, but also as a dumping ground for waste and production capital (Zulaicha, Sasana, & Septiani, 2020).

ASEAN countries are included in the category of Emerging Countries, where economic growth continues to increase supported by the agrarian and industrial sectors. According to the Organization for Economic Co-operation and Development (OECD), ASEAN is considered a driver of world economic growth (Ayuningrum, 2023). Developing countries that are considered as potential markets by world countries and growing as economic integration areas include Indonesia, Malaysia, the Philippines, Thailand, and Vietnam (Riyanto, 2015). These countries are in a critical phase of economic and environmental transition (Zafar, Ullah, Majeed, & Yasmeen, 2020). Compared to developed countries in East Asia such as Japan, South Korea, or even China, ASEAN emerging countries still face limitations in green technology, clean energy infrastructure, and strong environmental policies (Kuok, Sdok, Ho, & Muhamad, 2024). Meanwhile, according to Zeeshan, et al. (2022) compared to other developing regions such as Africa or Latin America, emerging countries in ASEAN have much more dynamic economic growth and faster industrialization rates, so they have the potential to be a significant contributor to global carbon emissions in the future.

The existence of dynamics of macroeconomic factors that affect each other, such as an increase in industrial activity reflected in GDP (Sazuli, 2025), foreign direct investment or FDI (Hapsari, 2023), Improving the quality of life of the community through the Human Development Index or HDI (Xu, et al., 2024), as well as increasing urbanization that accelerates economic concentration in urban areas (Wildani, Fratiwi, Hendra, & Amelinda, 2025). The increase in GDP is directly proportional to the exploitation of resources for industrialization. Because energy is the main driver of industrial productivity and household consumption in encouraging economic growth (Natavan Namazova, 2024).

Mirziyoyeva & Salahodjaev (2023), mentioning that in low-income countries, industrialization and the rapid growth of related industries spur pollution due to intensive economic activities and economic growth priorities. However, as GDP per capita increases, the adoption of energy-saving technologies and the development of industries with lower carbon footprints relieve pressure on the environment, and carbon emissions decrease. According to Tang, Tan, & Ozturk (2016), energy is considered an instrumental driver of economic growth, but it has been shown to increase air pollution.

Acemoglu (2009) states in modern approaches that technological advances can be endogenous, where economic growth is determined by investment decisions. This means that the process of capital accumulation and technological development can be systematically designed through appropriate economic policies and interventions (Simangunsong & Barika, 2025). One form of strategic investment is Foreign Direct Investment (FDI). FDI has a vital role in expanding production capacity, encouraging the modernization of the industrial sector, and increasing national efficiency and productivity (Riani & Iryani, 2023). One of the main issues often associated with FDI flows is increased emissions, especially when foreign investment is concentrated in energy-intensive and less environmentally friendly sectors CO_2(Sun & Han, 2022). Sazuli (2025) found that FDI affects CO2 in the long term as it is greater to the secondary sector over the past decade. On the other hand, Boateng, Annor, Amponsah, & Ayibor (2024) that FDI can consistently reduce CO2 emissions through policies to regulate the activities of foreign investors.

In developing countries, increases in HDI generally reflect success in expanding access to public services and infrastructure. However, an increase in HDI is often accompanied by growth in energy consumption, industrialization, and urbanization, which can directly drive increased CO2 emissions. Fakhri, Alqahtani, & Jamee (2024) and Costa, Rybski, & Kropp (2011) found that in the long term the influence of HDI on emissions depends on human quality. In line with CO_2 Xu, et al. (2024) and Alkam, Cakan, Sengul, & Ates (2024) found a positive relationship of high HDI to emissions Which, the increase in HDI in a reflects society being more environmentally friendly.

The urbanization process in the early stages tends to put great pressure on the environment due to weak governance systems and low environmental awareness (Hou, Liu, Zhang, Zhao, & Xia, 2019). However, urbanization also has the potential as a means of environmental efficiency if managed sustainably. Densely populated cities can reduce per capita emissions through mass transportation efficiency, centralized waste management, and the use of environmentally friendly technologies (Sadorsky, 2014). Studies by Wang, Wang, & Li (2022) show that the relationship between urbanization and carbon dioxide is non-linear, where at a certain level urbanization can reduce emission intensity if accompanied by supportive innovation and regulation. Ma & Ogata (2024), add that there is a heterogeneous impact of urbanization on carbon dioxide.

Based on this presentation, this study aims to serve as evidence and explore further the relationship between macroeconomic indicators and CO2 emissions in ASEAN Emerging Economies. This research has contributed to the development of science, especially in the fields of environmental economics and macroeconomics, enriching the empirical literature related to economic development and environmental sustainability. This research presents a new perspective by focusing on five ASEAN emerging countries (Indonesia, Malaysia, Thailand, the Philippines, and Vietnam) during the 2018–2023 period. The novelty of this study also lies in the integration of four macroeconomic variables, namely GDP, Urbanization, FDI, and HDI to analyze their influence on CO_2 emissions as well as the relationship between GDP and CO2 emissions through the ECC curve.

LITERATURE REVIEW

Externality Theory

Externality theory has strong relevance in explaining the relationship between economic activity, development, and the resulting socio-environmental impact. In general, externality is interpreted as the positive or negative impact of an action faced on a daily basis, not only limited to the management of natural resources (Veronica, 2015). Environmental externality is an impact in the form of benefits or costs arising from changes in physical and biological environmental conditions. That is, the existence of environmental externalities causes a difference between social benefits (or costs) and individual benefits (or costs), as a result of inefficient resource allocation (Yuniarti, 2019).

When this happens, markets tend to produce excessive or too little or less goods and services than socially optimal levels (Ashari & Angrraini, 2024). As a result, there is a market imbalance where demand and supply are not in an efficient equilibrium condition (Arimura, 2024). Thomas (2001) provides an alternative related to development paths and environmental quality, where an economy that pays attention to the environment will show an accelerated balance between economic development and environmental quality. If the economy adopts a "grow now, clean up latter" approach, there will be environmental degradation.

Environmental Kuznets Curve (EKC)

Kuznets' theory argues that the distribution of income is uneven at different levels of income growth. However, as the economy grows, the distribution of income tends to become more evenly distributed (Ananda & Prabowo, 2021). The reason for this is that when per capita

income increases, income inequality also increases at first after the maximum point begins to fall (Cahyani & Aminata, 2020). In the theory of EKC, the U-shaped relationship is inversely between per capita income and environmental degradation. In the early stages of economic growth and development, environmental degradation increased rapidly (Usenata, 2018). Nonetheless, once it reaches the threshold of economic development, the movement tends to reverse at a higher rate of economic progress (Fajar & Hariyanto, 2021).

As per capita income increases, government fiscal and institutional capacity tends to improve, allowing for more effective implementation of environmental regulations (Noor & Saputra, 2020). In addition, more prosperous societies tend to be more vocal in demanding a clean and healthy environment, thus pressuring policymakers to develop sustainable development strategies (Singh & Yadav, 2021). Simultaneously, advances in education and environmental awareness are reinforcing pressure on the industrial sector to internalize the external costs arising from pollutant activities (Fitriani, Diarto, & Yunitasari, 2025). Theoretically, the mechanism behind EKC is explained through the dynamics of industrialization and structural transition (Elfaki & Heriqbaldi, 2023). In the early stages, economic growth relies on resource-intensive sectors because economic priorities are more towards increasing production and job creation. However, as the country experienced continued economic growth, the service and technology sectors began to dominate the economic structure. These changes are usually accompanied by improved energy efficiency, the development of clean technologies, and the implementation of stricter environmental standards, which in aggregate reduce the level of environmental degradation (Christy & Sakti, 2022).

Green Growth Theory

Green Growth is an economic development paradigm that emphasizes the synergy between economic growth and environmental sustainability (Smulders, Toman, & Withagen, 2014). Different from conventional growth models that assume trade-offs between economic expansion and environmental protection, Green Growth emphasizes that ecologically sustainable growth is not only possible, but also essential for the long term (Hallegatte, Heal, Fay, & Treguer, 2012). This approach aims to increase economic productivity while ensuring that the natural resource base and environmental quality are maintained, and even improved, through innovation, efficiency, and institutional reform (Jacobs, 2012).

Theoretically, Green Growth is rooted in the concept of decoupling, which is the separation between the rate of economic growth and the pressure on the environment (Kampas, Rozakis, Faber, & Mamica, 2021). Relative decoupling occurs when emissions or degradation grow more slowly than GDP, while absolute decoupling means emissions or degradation decrease even though GDP continues to rise. The main objective of the Green Growth policy is to achieve absolute decoupling through the application of clean technology, energy efficiency, and sustainable resource management. Thus, growth is no longer exploitative of natural capital (Hickel & Kallis, 2007).

The concept of Green Growth also highlights the aspects of inclusivity and transitional justice. Therefore, it is important for Green Growth policies to include elements of social protection, green job creation, and transition support for affected sectors, such as fossil fuel-based industries. In other words, Green Growth does not only rely on GDP growth, but also on the quality of growth that includes social and ecological aspects in a balanced manner (ILO, 2018). At the macro level, Green Growth emphasizes the importance of public investment in green infrastructure, environmental education, and low-carbon technology research and development, in order to create a structural transformation towards a more efficient and climate-resilient economy (Sari & Setiyono, 2022).

Human Development

Human Development theory is a development approach that emphasizes that human welfare cannot be measured solely through economic growth, but must be seen from the extent to which development is able to expand human capabilities and freedom in living a life that they consider valuable. This idea is based on three main dimensions, namely health, education, and a decent standard of living. Within this framework, economic growth is just an instrument, while the ultimate goal is to improve the quality of human life (Efendi, Nasution, Rusiadi, & Pratiwi, 2024). The Human Development Index (HDI) as a measuring tool to assess human development achievements presents a new perspective in understanding development. The human development approach has fundamental differences from conventional development concepts, such as focusing on economic growth, human capital formation, resource development, social welfare, and meeting basic needs (Lerner, Hershberg, Hil, & Johnson, 2015).

GDP and CO_2 Emissions

Dong, Sun, Jiang, & Zeng (2018); Hasnisah, Azlina, & Taib (2019); Li, et al. (2022); Mitić, Fedajev, Radulescu, & Rehman (2023); Gazi, Nahiduzzaman, Shaturaev, Dhar, & Halim (2022); Osobajo, Otitoju, Otitoju, & Oke (2020); Akorede & Afroz (2020); Yazdi & Dariani (2019) found that GDP has a positive effect on CO2. This is because the more energy use and GDP the more CO2 is produced. On the other hand, the findings of Saidi & Omri (2020); Yazdi & Dariani (2019); Pilatowska & Geise (2021), found that GDP has a negative effect in the short term. Then, it was reinforced by Gazi, Nahiduzzaman, Shaturaev, Dhar, & Halim (2022) and Adebayo, Awosusi, Kirikkaleli, Akinsola, & Mwamba (2021) that GDP has a negative causality to CO2 in the short term.

H1: GDP has a positive and significant effect on CO2 emissions

Urbanization and CO_2 Emissions

Mighri, Sarwar, & Sarkodie (2022); Gazi, Nahiduzzaman, Shaturaev, Dhar, & Halim (2022); Adebayo, Awosusi, Kirikkaleli, Akinsola, & Mwamba (2021); Akorede & Afroz (2020); found that urbanization has a negative effect on CO2. This indicates that increasing urban populations actually reduces CO2 emissions. On the other hand, Li, et al., (2022) and Yazdi & Dariani (2019) found that the relationship between urbanization and CO2 is positively significant. So that energy and environmental policies are formulated without considering the effects of urbanization on CO2. Although in Asian countries, the population in urban areas is higher in terms of environmental pollution than other countries.

H2: Urbanization has a positive and significant effect on CO2 emissions

FDI and CO_2 Emissions

Gazi, Nahiduzzaman, Shaturaev, Dhar, & Halim (2022); Fitriani, Diarto, & Yunitasari (2025); and Huang, et al. (2022) found that FDI has a positive effect on CO2 and in the short and long term there is a causal relationship between FDI and CO2. Meanwhile, Li, et al., (2022) found that FDI lowers CO2 with the availability of resources and commitment to protect the environment and the support of green technology organizations. FDI helps to raise awareness about the environment so that the involvement of companies and individuals in activities that produce CO2 decreases. The existence of environmental control shows that the entity is strict to operate.

H3: FDI has a positive and significant effect on CO2 emissions

HDI and CO_2 Emissions

The results of a study conducted by Zheng & Wang (2022) and Akbar, Hussain, Akbar, & Ullah (2020) found that HDI has a negative effect on CO2. Recent infrastructure upgrades improve living standards and increase HDI (Liu, Poulova, Prazak, Ullah, & Nathaniel, 2023). In addition, countries (or groups of countries) that have reached a stage in improving human

development come more from education, health care, and clean technology, rather than from the growth of polluting industries.

In research conducted by Ahmed & Alhassoon (2024); Issaoui, Alqahtani, & Jamee (2024) and Bieth (2020) found positive results on the relationship between HDI and CO2. Analysis using ARDL conducted by Ahmed & Alhassoon (2024), found that positive shocks had a significant impact after examining the impact of CO2 shocks. After positive shocks, HDI then stabilized. This shows that the positive shock of CO2 has only a small impact on the increase in the HDI index. Then, Alqahtani, & Jamee (2024) and Bieth (2020) affirm that there are two strong theories that contradict each other. The first theory asserts that HDI is negatively affected by CO2 emissions, while the second theory supports that increases in human development are still recorded in the most polluting countries (countries that emit the most emissions, but may not immediately feel the impact in their own countries).

H4: HDI has a negative and significant effect on CO2 emissions

METHODS

To test the relationship between macroeconomic indicators and CO2 emissions in ASEAN emerging countries (Indonesia, Malaysia, Thailand, the Philippines, and Vietnam) in a longitudinal time span from 2018 to 2023, data was collected from international statistical institutions such as our world in data and asean stats. In addition, important attention from this study is focused on the relationship of macroeconomic indicators (Gross Domestic Product, Urbanization, Foreign Direct Investment, and Human Development Index) to CO2 Emissions as a dependent variable. Meanwhile, to analyze the relationship between the dynamics of macroeconomic indicators and CO2 emissions in ASEAN emerging countries, a multiple linear regression method was used with a descriptive quantitative approach. The regression model serves to examine the relationship or influence of two or more independent variables on the dependent variable (Gujarati & Porter, 2008). The equation shows a model of the relationship between the variables in this study. CO2 emissions are measured in tons per person, GDP per capita is measured in US dollars, urbanization is measured in the number of people, FDI is measured in million dollars and HDI is measured in indices. The regression equation in this study is as follows:

$$CO_{2_{it}} = \beta_{0i} + \beta_1 GDP_{it} + \beta_2 \ln\_URB_{it} + \beta_3 \ln\_FDI_{it} + \beta_4 HDI_{it} + \varepsilon_{it}$$

If all individual, time, and random noise disturbances are combined into one and follow all the initial assumptions of normally-free and identically distributed random noise, then the use of the GLS method will produce estimates that are best linear and unbiased. This method is known as the Random Effect Model or Error Components Model. However, if all assumptions on the disturbance are not stated to follow the assumption of random noise, then the use of OLS and GLS methods will not provide results that meet the best linear and unbiased properties (Baltagi, 2005). In this way, the inter-temporal disturbances and inter-individual components will be incorporated into the intercept constant of the model. This is what is referred to as the Fixed Effect Model.

Based on this, the best model selection is done by conducting the Chow Test and the Hausman Test. The Chow test is used to see the comparison between the Common Effect Model (CEM) and the Fixed Effect Model (FEM). Meanwhile, the Hausman Test looks at the comparison between the Random Effect Model (REM) and the Fixed Effect Model. Furthermore, classical assumption tests in the form of multicollinearity and heteroscedasticity are carried out to fulfill the requirements of regression analysis in the form of best linear unbiased.

Theoretically, the advantage of using panel data is that the greater the number of observations, will provide positive population parameter estimates will be and increase degrees of freedom, as well as reduce the possibility of collinearity between independent variables. In the linear regression equation model, the error disturbance is always stated to be homoscedastic

and serially uncorrelated. Thus, the use of the Ordinary Least Squares (OLS) method will produce estimates that are best linear and unbiased. However, these assumptions cannot be applied to panel data. Therefore, the OLS method is used separately to estimate each variable on life satisfaction in each country.

RESULTS

Classical assumption testing is performed to detect problems in the relationships between independent variables as well as the variance stability of errors. Testing of classical assumptions includes multicollinearity and heterokedasticity tests. The multicollinearity test in this study uses the value of VIF where when the value is more than 10, multicollinearity occurs. Table 1. indicates that the VIF value for all independent variables is less than 10. Thus, the independent variables used in the study were not related to each other or multicolonialism did not occur.

Table 1. Multicollinearity Test Results

Independent Variables	VIF	1/VIF
Gross Domestic Product	5.15	0.194311
Urbanization	2.59	0.386125
Foreign Direct Investment	1.54	0.648649
Human Development Index	6.84	0.146296
Mean VIF	4.03	

Source: Data Processed, 2026

The Breusch–Pagan/Cook–Weisberg test is used to detect heteroscedasticity, which is a condition in which the variance of the residual (error term) is not constant across observations. The results of the heterokedasticity test are presented in Table 2. using Breusch-Pagan which shows the result that the Prob > Chi2 > α with a value of 0.3289 > 0.05. This means that the variance of the error in the regression model is constant or heterokedasticity does not occur.

Table 2. Heterokedasticity Test Results

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	
Ho	: Constant Variance
Variables	: Fitted values of co2
Chi2(1)	: 0.95
Prob > Chi2	: 0.3289

Source: Data Processed, 2026

The selection of the best model is carried out by testing the CEM, FEM, and REM models through the Chow test, Hausman test, and Lagrange Multiplier (LM) test. Table 3. showed that in the first test, the results of the Chow test conducted by comparing the CEM and FEM models were obtained that the Prob value > F was 0.0000. This value is less than 0.05 so the selected model is FEM. Then, the second test was continued, namely the Hausman test by comparing REM and FEM.

The results showed that the value of Prob > F of 0.0634 was greater than 0.05 (0.0634 > 0.05). So, the model selected in this test is REM. Therefore, a third test is needed to determine the best model through LM tests by comparing CEM and REM models. The result was obtained that the value of the Prob > chi2 of 0.0000 was less than 0.05. So, the selected model is REM.

Table 3. Best Model Selection

Test Type	Alpha (α)	Prob F	Selected Models
Chow test	0.05	0.0000	FEM
Hausman test	0.05	0.0634	REM
LM test	0.05	0.0000	REM

Source: Data Processed, 2026

Table 3 Showing the regression results of the best selected model, namely the Random Effect Effect (REM). The Coefficient of Determination (R2) test is based on the use of Generalized Least Squares (GLS) which combines variation between individuals (between) and variation within individuals (within) simultaneously. Then the most appropriate measure of model accuracy to use is R^2 overall. It was found that the overall R2 value was 0.9501. This means that 95.01 percent of macroeconomic variables can explain CO2 emission variables. The remaining 4.99 percent is influenced by other variables outside the model. Simultaneously, the macroeconomic indicator variables used had a significant relationship with the prob value >chi2 of 0.0000 < 0.05. Meanwhile, in general, the variables of GDP, Urbanization, and FDI are significant to CO2 emissions.

Tabel 4. Regression Results

Construct	Coef.	Standard Error	z	p>|z|
CO2 per Capita	22.32981	8.053802	2.77	0.000
GDP per Capita	.0003201	.00003	10.68	0.000
ln_Urbanisasi	-.9301263	.2721177	-3.42	0.001
ln_FDI	.7412962	.2521373	2.94	0.003
HDI	-12.48975	6.601465	-1.89	0.058

Note. R^2 = .9501; Prob>chi2= .0000 (p < .05)

The relationship between GDP and CO2 emissions is positive. An increase in GDP by 1 US dollar will increase CO2 emissions by 0.0003201 tons per person. Urbanization has a negative influence and shows that when urbanization increases by 1 percent, it will reduce CO2 emissions by 0.9301263 tons per person. FDI has a positive influence and shows that when FDI increases by 1 percent, it increases CO2 emissions by 0.7412962 tons per person. HDI has a negative influence and shows that when HDI rises by 1 point, it reduces CO2 emissions by 12.48975 tons per person.

DISCUSSION

GDP has a positive and significant influence on CO2 Emissions. These findings indicate that the increase in economic activity reflected in the increase in GDP tends to be accompanied by an increase in CO2 emissions. In line with the EKC theory which states that in the early stages of development, economic growth and environmental degradation have an inverted U-curve shape. In line with this, proof is carried out through the EKC curve through Figure 1. which shows that ASEAN emerging countries are still in the early stages of development. The existence of increased economic activity at the expense of the environment, the dominance of energy-intensive industries and the exploitation of natural resources.

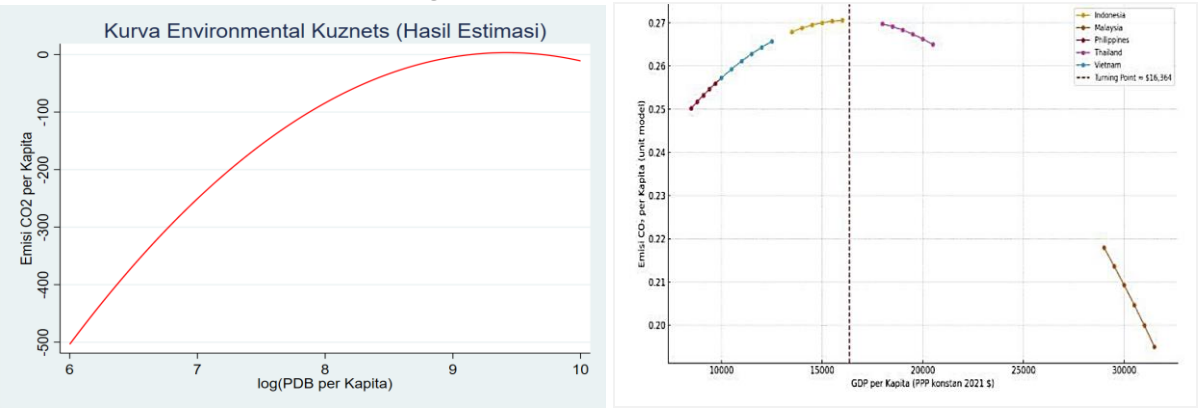
These results are supported by research conducted by Dong, Sun, and Zeng (2018); Hasnisah and Taib (2019); Li, et al., (2022); Mitić, Fedajev, Radulescu, & Rehman (2023); Gazi, Nahiduzzaman, Shaturaev, Dhar, & Halim (2022); Osobajo, Otitoju, Otitoju, & Oke (2020); Akorede & Afroz (2020); and Yazdi & Dariani (2019) found that GDP has a positive effect on CO2. This is because the more energy use and the increase in GDP, the more CO2 is produced. It is

emphasized by Yunita, Gunarto, Marselina, & Yuliawan (2023), that GDP per capita has a positive and significant influence on CO2 emissions both in the short and long term. An increase in GDP per capita can increase energy consumption and industrial production, which contributes to an increase in CO2 emissions. Increased production and energy consumption will increase the use of fossil fuels, which are a major source of CO2 emissions.

Research conducted by Nusantara, et al. (2025), estimates that until 2030 it shows that the Turning Point of emissions is at GDP per Capita of around $16,364. This point marks the income level at which a country's CO2 Emissions per Capita reach its peak before finally starting to decline as income continues to rise. Vietnam and the Philippines are still in the early stages of development, so the increase in GDP is still correlated with the phase of increasing CO2 emissions. Meanwhile, Malaysia and Thailand are starting to approach a turning point, where an increase in income is starting to be accompanied by better environmental awareness and policies. Meanwhile, Indonesia seems to be moving in a phase of reducing emissions, which shows that although economic growth continues, the per capita emission rate tends to decline. This can be attributed to the start of the implementation of renewable energy policies and energy efficiency in the industrial sector.

Analysis for each country shows that there is a positive influence of GDP on CO2 emissions with an increase of 0.0001 tons per person for every 1 dollar increase in Indonesia and Malaysia. Meanwhile, the Philippines and Thailand contribute CO2 emissions of 0.0000 tons per person for every 1 dollar increase in GDP. The highest increase occurred in Vietnam with a CO2 emission value of 0.003 tons per person for every GDP of 1 dollar. Referring to research conducted by Thu, Hanh, Nguyen, Luong, & Hue (2022), economic growth in Vietnam is going hand in hand with increasing CO_2 emissions due to the pace of development that is still heavily dependent on fossil-based energy. As GDP increases, industrial, manufacturing, and infrastructure development activities also grow. These sectors require a large supply of energy, and most of the energy in Vietnam still comes from coal, oil, and gas. Dependence on these energy sources causes every increase in production and economic expansion to be followed by an increase in carbon emissions. In addition, the increase in people's income increases household consumption such as the purchase of private vehicles, electricity needs, and other electronic devices. As a result, economic growth, energy consumption, and CO_2 emissions are moving in the same direction.

Figure 1 Kurva Environmental



Source: Data Processed, 2026

Urbanization has a negative and significant effect on CO2, which results are not in accordance with the research hypothesis. Findings of Mighri, Sarwar, & Sarkodie (2022); Gazi, Nahiduzzaman, Shaturaev, Dhar, & Halim (2022); Adebayo, Awosusi, Kirikkaleli, Akinsola, & Mwamba (2021); Akorede & Afroz (2020) and Sharma (2011) found that urbanization has a negative effect on CO2. This indicates that an increase in urban population actually reduces CO2

emissions. Tang & Hu (2023), found the same results that there are negative effects of urbanization that actually reduce CO2 emissions. This phenomenon can be explained through Tiebout's theory of voting with one's feet, which states that residents or economic actors will move to areas with a combination of public policies, environmental quality, and better facilities. This means that if a region implements sustainable urbanization policies and a clean environment, it attracts population migration and economic activity from areas with high pollution levels. Thus, spatially, there is a decrease in carbon emissions in other regions.

Keho (2023), conducted a mapping of 135 studies for the impact of urbanization on CO2 emissions and found that urbanization can have both positive and negative impacts. This refers to the theories used in the form of ecological modernization theory, urban environmental transition theory, and compact city theory. More prosperous people are also usually more concerned about environmental issues. In addition, more affluent communities are also more encouraged to provide financial support for green projects as well as invest in modern technologies. Urbanization also creates economies of scale in the provision of public infrastructure such as clean water, health facilities, education, and transportation. In line with this, the analysis of each country shows that 4 countries, namely Malaysia, the Philippines, Thailand, and Vietnam, have a negative impact between urbanization on CO2 emissions. This is because populations in urban areas can create energy efficiency, reduce fuel intensity, and reduce emissions per capita through the consolidation of public services, mass transportation, and centralized infrastructure.

The tie, on the other hand, shows that urban development drives economic growth which increases per capita income. People with higher income levels tend to consume more eco-resource-intensive goods and services, which can reduce biocapacity and worsen their ecological footprint. This is proven to be the only Indonesia that has a positive influence of urbanization on CO2 emissions. The increase in Co2 emissions by 1,201 tons per person is caused by 1 person moving to the city. Li, et al., (2022) and Yazdi & Dariani (2019) found that the relationship between urbanization and CO2 is positive indicating that energy and environmental policies are formulated without considering the effects of urbanization on CO2. Hasanah & Wu (2023), found that in Indonesia, especially in urban areas, there are varying levels of emissions with Jakarta, Surabaya, Medan, Pekanbaru, and Bandung dominating the level of CO2 emissions with a high population. Cities with high levels of urbanization and increased CO2 emissions indicate high levels of development and the economy as well as broader environmental degradation. In addition, the attractiveness of cities as a provider of employment is in great demand by people living in rural areas.

FDI has a positive effect on CO2 emissions, which is in accordance with the research hypothesis. In line with the theory of externalities, economic activities (such as industrial investment) can produce an aberrant impact on the environment that is reflected in a company's production costs. Foreign companies investing in developing countries often move energy-intensive and pollution-intensive industries to host countries that have looser environmental regulations. As a result, although FDI increases economic output and job creation, it causes negative externalities in the form of increased CO2 emissions and environmental degradation. This phenomenon is known as the Pollution Haven Hypothesis (PHH), which is a derivative of the theory of externality (Tsandra, Sunaryo, Syafri, & Octavian, 2023). This theory states that FDI tends to flow to countries with low environmental standards. In line with this, Gazi et al., (2022); Fitriani, Diarto, & Yunitasari (2025); and Huang, et al. (2022) found that FDI has a positive effect on CO2 both in the short and long term there is a causal relationship between FDI and CO2. Alvika & Busneti (2025), show that FDI has a positive influence on CO2 emissions. This means that FDI from abroad in their operational activities still uses technology that is not environmentally friendly, thereby worsening environmental quality.

Of the 5 ASEAN emerging countries, 4 of them, namely Indonesia, Malaysia, the Philippines, and Thailand, have a positive influence of FDI on CO2 emissions. Li & Zhou (2025),

mentioned that this influence is due to, first, investment in high-polluting industries such as coal, oil, and heavy industries still dominating. Second, resource development is driven by short-term interests. For example, overinvestment in industries such as mining, logging, and agriculture leads to deforestation, depletion of water resources, and soil degradation, which threatens the ecological balance. Third, externalization of environmental costs. Fourth, financial speculation and resource bubbles by overexploiting.

Among the 4 countries that have a positive influence of FDI on CO2 emissions, Indonesia ranks first with an increase of 0.695 tons per person if FDI increases by 1 dollar. According to Sasana, Sugiharti, & Yuliani (2018) FDI has a significant positive effect on CO2 emissions, this indicates that production activities carried out by multinational companies have an impact on environmental degradation. It is undeniable that the increasing number of economic development activities that lead to industrialization can improve people's welfare, but on the other hand it has reduced the quality of the environment. In 2017, no less than 30,000 industries flourished in Indonesia and will continue to grow every year. The emergence of the era of industrialization marked by the establishment of factories that produce various kinds of human needs has increased welfare, but on the other hand the level of environmental pollution is also increasing.

A different thing is happening in Vietnam, where FDI has a negative effect on CO2 emissions. The existence of carbon market mechanisms and stronger environmental regulations in Vietnam strengthens the incentives for foreign investors to adopt cleaner technologies. The government realizes that carbon market mechanisms are the most economically efficient way to reduce emissions, while opening up new access to funding for green projects. In addition, Vietnam also faces external pressures such as the implementation of the European Union's Carbon Border Adjustment Mechanism (CBAM), so Vietnamese companies need to reduce emissions to remain competitive in the export market

Li, et al., (2022) found that FDI lowers CO2 with the availability of resources and a commitment to protecting the environment and organizational support in the field of green technology. FDI helps to raise awareness about the environment so that the involvement of companies and individuals in activities that produce CO2 decreases. The existence of environmental control shows that the entity is strict to operate. This is in line with the Pollution Halo hypothesis theory that shows that economic activities through FDI are more efficient, i.e. using modern technology that is more effective to produce greater output (Tsandra, Sunaryo, Syafri, & Octavian, 2023). FDI inflows are increasingly dominated by the services sector, which tends to contribute less to emissions through clean technology transfer and more efficient production practices, compared to the manufacturing and mining sectors, which contribute significantly to CO2 emissions.

HDI has a negative and insignificant effect on CO2 emissions, which is not in accordance with the research hypothesis. In accordance with Human Development theory, when the three dimensions (health, education, and decent living standards) increase, public awareness of the importance of environmental quality also tends to increase. Communities with higher levels of education and better access to health care will have a stronger understanding of the negative impact of pollution on life. In addition, a more decent standard of living allows individuals and households to switch to more environmentally friendly consumption and production patterns.

Countries with high HDI typically have stricter environmental regulations, technological innovations that support renewable energy, and a more aware society of the importance of maintaining ecological balance. The results of research conducted by Fitriani, Diarto, & Yunitasari (2025); Zheng & Wang (2022); and Akbar, Hussain, Akbar, & Ullah (2020) found that HDI has a negative effect on CO2. Recent infrastructure upgrades improve living standards and increase HDI (Liu, Poulova, Prazak, Ullah, & Nathaniel, 2023). In addition, countries (or groups of countries) that have reached a stage in improving human development come more from

education, health care, and clean technology, rather than from the growth of polluting industries.

Of the 5 countries studied, only Thailand is in accordance with the research hypothesis which has a negative influence between HDI on CO2 emissions. An increase in HDI by 1 point can reduce CO2 emissions by 4.09 tons per person. Referring to Thailand's Third Biennial Update Report (2020), Thailand has included the issue of climate change in its national economic and social development plans since 2007. Currently, climate change is a concern at the highest policy level under the National Strategy (2018–2037) to ensure the long-term sustainability of the issue in line with other economic and social considerations. The Climate Change Master Plan 2015–2050 includes aspects of climate change mitigation and adaptation, capacity building, and the creation of a supportive environment. The other four countries (Indonesia, Malaysia, the Philippines, and Vietnam) show a positive relationship between HDI and CO2 emissions. In Indonesia and the Philippines, the increase in HDI is often accompanied by dependence on fossil energy, especially coal and oil, so that any progress in human development has consequences in the form of increased carbon emissions. Meanwhile, in Malaysia and Vietnam, rapid increases in human development have encouraged the expansion of economic sectors such as manufacturing, transportation, and urbanization. Modernization in the education and health sectors requires greater infrastructure, the use of technology, air conditioning, and other supporting facilities that still rely on carbon-based energy.

In research conducted by Ahmed & Alhassoon (2024); Issaoui, Alqahtani, & Jamee (2024); and Bieth (2020) found positive results on the relationship between HDI and CO2. Analysis using ARDL conducted by Ahmed & Alhassoon (2024), found that positive shocks had a significant impact after examining the impact of CO2 shocks. After positive shocks, HDI then stabilized. This shows that the positive shock of CO2 has only a small impact on the increase in the HDI index. Pratiwi, Purbadharmaja, & Yasa (2024), show that the improvement in the quality of human development reflected through improving education, health, and living standards is still followed by increased fossil-based energy consumption. In the context of developing countries in the ASEAN region, the increase in HDI is generally accompanied by increased economic activity, urbanization, and the use of energy for transportation and industries that are not yet environmentally friendly. In addition, limited access to clean technology and renewable energy causes increased welfare and has the potential to increase carbon emissions. Low public awareness of sustainable development issues and weak implementation of environmental policies also strengthen the positive relationship between HDI and CO_2 emissions.

CONCLUSION

GDP has a positive and significant influence on CO2 Emissions. These findings indicate that the increase in economic activity reflected in the increase in GDP tends to be accompanied by an increase in CO2 emissions. In line with the EKC theory which states that in the early stages of development, economic growth and environmental degradation have an inverted U-curve shape. Urbanization has a negative and significant effect on CO2. The existence of sustainable urbanization policies and a clean environment attract population migration and economic activity from areas with high levels of pollution. Thus, spatially, there is a decrease in carbon emissions in other regions. FDI has a positive effect on CO2 emissions, which is in accordance with the research hypothesis. In line with the theory of externalities, economic activities (such as industrial investment) can produce an aberrant impact on the environment that is reflected in a company's production costs.

Foreign companies investing in developing countries often move energy-intensive and pollution-intensive industries to host countries that have looser environmental regulations. HDI has a negative and insignificant effect on CO2 emissions, which is not in accordance with the research hypothesis. In accordance with Human Development theory, when the three

dimensions (health, education, and decent living standards) increase, public awareness of the importance of environmental quality also tends to increase. Communities with higher levels of education and better access to health care will have a stronger understanding of the negative impact of pollution on life.

LIMITATION

This study uses a research time span covering six years to make long-term dynamics, such as economic structural changes, energy transitions, and green technology developments, not fully captured. As a result, variable relationship patterns may not yet reflect long-term trends. Research variables on major macroeconomic factors. The study only used GDP, urbanization, FDI, and HDI, so other important factors such as energy consumption, industrial structure, renewable energy use, national environmental policies, and institutional quality were not included in the model. Expanding the time span and number of countries for long-term analysis Further research is suggested using a longer time period or including more developing countries to capture the structural dynamics, energy transition trends, as well as economic volatility affecting CO_2 emissions.

Future research can include variables such as fossil energy consumption, renewable energy use, industrialization rate, institutional quality, environmental regulations, transportation, and green technology indexes. This can enrich the model and reduce potential bias. Advanced research can test models with methods such as Fixed Effect, Dynamic Panel (GMM), or ARDL-panel that are capable of capturing short- and long-term relationships at the same time. In addition, Granger causality testing can provide a deeper understanding of the direction of inter-variable relationships.

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