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Research article

Does Growth Have an Impact on CO_2 Emission in ASEAN Countries?

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Abstract: The impact of global warming is alarming, posing significant threats to human health and the environment. They were primarily caused by increased greenhouse gases (GHG), especially CO_2, which accounts for 70% of emissions. This study analyzes the impact of the Gross Domestic Product (GDP) per capita, Human Development Index (HDI), and population on CO_2 emissions in ASEAN countries using a panel data regression methodology and secondary data from the World Bank and Global Economy Website (2000-2020). Fixed Effect Model Result via E-views 10 reveals that HDI and population have positive but non-significant effects on CO_2 emissions. In contrast, GDP per capita has a positive and significant effect, driven by increased consumption of fossil fuels. Governments play a crucial role in mitigating these effects through renewable energy, clean technologies, and environmental education to ensure sustainable development. Future research needs to design incentives to support environmental and economic sustainability.

Keywords: CO_2 emission, GDP per capita, human development index, population, ASEAN

JEL Classification: I32, Q53

Abstrak: Dampak pemanasan global sangat mengkhawatirkan, menimbulkan ancaman signifikan bagi kesehatan manusia dan lingkungan. Pemanasan global terutama disebabkan oleh peningkatan gas rumah kaca (GRK), khususnya CO_2, yang menyumbang 70% dari emisi. Studi ini menganalisis pengaruh Produk Domestik Bruto (PDB) per kapita, Indeks Pembangunan Manusia (IPM), dan populasi terhadap emisi CO_2 di negara-negara ASEAN menggunakan metodologi regresi data panel dan data sekunder dari Bank Dunia dan Situs Ekonomi Global (2000-2020). Hasil Fixed Effect Model melalui E-views 10 menunjukkan bahwa IPM dan populasi memiliki efek positif tetapi tidak signifikan terhadap emisi CO_2, sementara PDB per kapita memiliki efek positif dan signifikan, didorong oleh peningkatan konsumsi bahan bakar fosil. Pemerintah memainkan peran penting dalam mengurangi efek ini melalui energi terbarukan, teknologi bersih, dan pendidikan lingkungan untuk memastikan pembangunan berkelanjutan. Penelitian di masa depan perlu merancang insentif untuk mendukung keberlanjutan lingkungan dan ekonomi.

Kata kunci: limbah CO_2, PDB per kapita, Indeks pembangunan manusia, jumlah penduduk, ASEAN

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1. INTRODUCTION

Sustainable development has become an increasingly crucial topic in global discussions as nations strive to balance economic growth, social equity, and environmental protection. It aims not only to meet current needs but also to ensure that future generations have the resources and opportunities to thrive. The phenomenon of global warming, caused by the increase in greenhouse gases (GHGs) resulting from various economic activities—namely production, consumption, and distribution—poses a significant threat to this balance. While GHGs occur naturally, human activities exacerbate their concentration, leading to rising global temperatures. Carbon dioxide (CO_2) emissions, which are the most common GHG contribute significantly to global warming. Since 2020, CO_2 emission concentrations in the atmosphere have increased by around 48% (European Commission, 2022). The World Meteorological Organization (WMO) identifies CO_2 as the primary driver of global warming (GAW-WMO, 2017).

Developing countries face unique challenges, including rapid urbanization, population growth, and limited financial resources, which often exacerbate environmental degradation and social inequality. The ASEAN region in particular has experienced substantial economic growth, urbanization, and population increases, which, while fostering economic prosperity, have also presented significant environmental challenges, especially concerning CO_2 emissions. Recent reports indicate that CO_2 levels in the ASEAN region remain a cause for concern. The CO_2 emissions per capita from 2000 to 2020 highlight significant variations across the region. Singapore and Brunei Darussalam consistently show the highest per capita CO_2 emissions. In contrast, Indonesia, the Philippines, Myanmar, Cambodia, Laos, and Timor Leste show much lower per capita emissions, with gradual increases and minimal fluctuations. For instance, Indonesia's emissions increased from 1.3 to 2.1 metric tons per capita, while the Philippines remained relatively stable around 1.3 metric tons per capita by 2020. Myanmar, Cambodia, Laos, and Timor Leste all started at low levels and exhibited slight increases over the two decades. This disparity in CO_2 emissions per capita among ASEAN countries reflects the diverse levels of economic development, industrialization, and environmental policies within the region, underscoring the complex interplay between economic growth and environmental sustainability challenges by these nations.

Numerous factors influence CO_2 emissions. Suparmoko (2000) and Hove et al. (2020) highlight the detrimental effects of economic development activities on the environment, such as damage and pollution. Studies by Adikari et al. (2023) and Gede et al. (2018) indicates that enhanced human development, as measured by the Human Development Index (HDI), education, and human capital, leads to better environmental sustainability by reducing ecological footprints, CO_2 emissions, total GHGs, and exposure to air pollution. These findings underscore the positive contribution of human development towards ensuring environmental sustainability. Human development, often considered as an increase in education, health, and living standards, is a crucial driver of economic growth and plays a significant role in the technological progress of a country (Teixeira & Queirós, 2016; Jenouvrier et al., 2018 & Khan et al., 2021).

Human development is crucial, as higher education enhances productivity, responsibility, and innovation, leading to new ideas and efficient methods (Teixeira & Queirós, 2016; Chankseliani et al., 2021). It is also essential for environmental preservation, as understanding the environment and climate change is vital for effective mitigation (Ahmad et al., 2022; Bano et al., 2018). Education fosters responsibility for environmental sustainability and helps people protect their environment (Opoku et al., 2022). Žalėnienė & Pereira (2021) showed that higher education and income increase recycling activities. Educated individuals better understand environmental degradation complexities, such as global warming (Chankrajang & Muttarak, 2017). An increase in the Human Development Index (HDI) usually leads to changes in consumption patterns. More educated and healthier people have a higher awareness of environmental impacts. As prosperity increases, society demands better living environments (Zhang et al., 2021), driving demand for sustainable products and services. As living standards rise, concern for the environment increases, as people can afford a less polluted environment. Income, a component of HDI, captures living standards, while education helps the public understand the importance of protecting the environment. Therefore, a better HDI is expected to improve environmental quality. However, Tran et al. (2019) found that while increased human development in developed countries reduces carbon emissions, this is not observed in developing countries in the short run.

Economic growth can also influence the environment, leading to deforestation, land degradation, water pollution, and atmospheric pollution. Sixty percent of CO_2 emissions come from energy-intensive sectors such as industry, transportation, housing, and commerce, with 25 percent from forestry and 15 percent from agriculture (WRI, 2022). Energy consumption significantly affects CO_2 emissions, influenced by population size, economic growth, and technological developments (Mitić et al., 2023). Salahuddin et al. (2018) found that a one percent increase in per capita electrical energy consumption increases per capita CO_2 emissions. Qin et al. (2020) confirmed that changes in energy consumption levels and population are the main factors influencing carbon emissions, with economic growth and energy consumption affecting CO_2 emissions (Darrian et al., 2023).

The study by Pertiwi et al. (2024) on G20 countries from 2000 to 2022 found that economic growth is positively related to CO_2 emissions. As the economy grows, CO_2 emissions increase due to energy-intensive activities. However, the study also identified the Environmental Kuznets Curve (EKC) theory, suggesting that beyond a certain level of economic development, the relationship between economic growth and CO_2 emissions can be inverted. At higher income levels, CO_2 emissions may decrease due to increased environmental awareness, technological advancements, and more sustainable practices (Galeotti, 2007). This turning point, where economic growth reduces environmental degradation, is described by Aminata et al. (2022). A study by Aye and Edoja (2017) found significant causal relationships between CO_2 emissions, economic growth, energy consumption, and financial development in developing countries.

As most ASEAN countries are developing nations, they exhibit significant variations in population size. Rapid population growth in some countries may contribute to greater environmental pressure due to increased consumption, particularly in energy, which promotes emissions. Moreover, it worsens the impact of climate change, driving higher risk exposure (Dolge & Blumberga, 2021). Kan et al. (2021) found that renewable energy consumption, population growth, and biocapacity positively correlated with ecological footprint and CO_2 emissions in the USA from 1971 to 2016. Population growth contributes to declining environmental quality. In China, urban population growth significantly drives CO_2 emissions in cities, with a 1% increase in urban population size leading to nearly a 1% rise in total CO_2 emissions and a 0.3% decrease in per capita CO_2 emissions (Liu et al., 2021). High economic agglomeration also leads to more CO_2 emissions. Zarco-Periñán et al. (2021) found that population density impacts energy consumption and CO_2 emissions in Spanish cities with populations over 50,000, showing that CO_2 emissions from electrical sources are more significant than those from thermal sources but decrease in proportion as density increases. Pertiwi et al. (2024) found that population has a negative correlation with CO_2 emissions within G20 countries, which may reflect increased environmental awareness and sustainable practices among larger populations. Higher population densities can lead to economies of scale in implementing green technologies and infrastructure, reducing the overall carbon footprint.

Many studies highlight the complex interplay between the Human Development Index (HDI), economic growth, population dynamics, and CO_2 emissions globally, but similar studies is lacking in ASEAN countries. While ASEAN nations have experienced significant economic growth in recent decades, driven by industrialization and urbanization, the relationship between this growth and CO_2 emissions varies across the region. Some countries have managed to achieve notable economic development while keeping emissions relatively low, while others struggle to balance economic expansion with environmental sustainability, resulting in higher per capita emissions. Rapid population growth in certain ASEAN countries further strains resources and infrastructure, potentially exacerbating emissions. This study aims to bridge these gaps by examining the relationship between human development, economic growth, and population size on CO_2 emissions in ASEAN countries and formulating effective strategies for sustainable development and emissions reduction tailored to the region's needs. This study has significant implications for policy development, particularly concerning environmental quality.

2. RESEARCH METHODS

This study uses secondary data from various sources, including online newspapers, academic articles, and data from the World Bank, the United Nations, and the Global Economy website. CO_2 emissions serve as the dependent variable in this study, with data sourced from the World Bank. The CO_2 emissions data encompass total greenhouse gas emissions in kilotons of CO_2 equivalent, excluding short-cycle biomass burning (e.g., agricultural waste burning) but including other biomass burning (e.g., forest fires, post-burn decay), all anthropogenic CH_4 sources, N2O sources, and F-gases (HFCs, PFCs, and SF6). The independent variables considered are the Human Development Index (HDI), GDP per capita, and population size, with data sourced from the World Bank and the United Nations.

This study employs panel data, consisting of time series data over 21 years (2000 to 2020) and cross-sectional data for each ASEAN country (Singapore, Brunei Darussalam, Thailand, Malaysia, Laos, Myanmar, Vietnam, Indonesia, the Philippines, Cambodia, and Timor-Leste). Using panel regression to analyze the relationship between HDI, economic growth, population, and CO_2 emissions in ASEAN countries offers several advantages. Firstly, panel data combine cross-sectional and time-series data, providing a comprehensive analysis that accounts for variations across countries and over time, enabling the identification of long-run trends and short-run fluctuations. Secondly, panel regression controls for unobserved heterogeneity, referring to country-specific factors that may influence CO_2 emissions but are not directly measured, resulting in more accurate and reliable estimates. Thirdly, it facilitates the exploration of dynamic relationships, such as how changes in HDI or economic growth over time impact CO_2 emissions. By using panel regression, researchers can account for the complex interplay between development indicators and environmental outcomes in the diverse and rapidly evolving context of ASEAN countries, leading to more robust and policy-relevant insights. The panel data model is estimated as follows:

$$CO2_{i,t} = f(GDPPC_{i,t}, HDI_{i,t}, POP_{i,t}) \quad (1)$$

Next, Some of the variables are transformed using the logarithmic model to enhance regression efficiency, stabilize variance, and linearize the relationships within the data as follows:

$$logCO2_{i,t} = \beta_0 + \beta_1 logGDPPC_{i,t} + \beta_2 HDI_{i,t} + \beta_3\, logPOP_{i,t} + \varepsilon_{it} \quad (2)$$

where, CO_2 represents total greenhouse gas emissions measured in kilotons of CO_2 equivalent; HDI denotes the human development index, which includes indicators such as life expectancy, education level, and per capita income; the GDPPC stands for GDP per capita, calculated as the total gross value added by all resident producers in the economy, including product taxes (minus subsidies) not accounted for in the output valuation, divided by the mid-year population, measured in US dollars; POP represents population size data, encompassing all residents regardless of legal status or citizenship, sourced from the World Bank website. In the statistical context of the study, t denotes time; i signifies the cross-section (1....N); and epsilon (ε) stands for the residual term, representing unexplained variability in the model.

The study employed the Chow and Hausman test to determine the appropriate model specification, choosing between common, fixed, or random effects models based on the data characteristics and assumptions. To ensure the robustness and reliability of the panel data regression model, conducting a unit root test is crucial to assess the stationarity of the data series. Stationarity is essential to avoid spurious results and ensure meaningful long-run relationships in the analysis. Additionally, it is necessary to verify residual diagnostic such as homoscedasticity, absence of multicollinearity, and normality of residuals. These checks are vital to validate the model's assumptions and ensure that its estimations are unbiased, efficient, and consistent. Ultimately, rigorous testing of these assumptions enhances the reliability of findings and strengthens the validity of policy recommendations derived from the model.

3. RESULTS AND DISCUSSION

This session will describe the results of a quantitative analysis of the correlation of GDP per capita, HDI and population size on CO_2 emissions in ASEAN countries from 2000 to 2020. The analysis of the results will be continued and ends with a discussion regarding the complex impact of GDP per capita, HDI as well as population size on CO_2 emissions. This discussion also tries to provide suggestions regarding interventions that may be needed to reduce CO_2 emissions and encourage the implementation of sustainable economic development.

Descriptive statistics are used to show the amount of data as a sample used in the study, in addition to knowing the lowest value, highest value, average value, and standard deviation. The results of descriptive statistics for the variables GDP per capita, HDI, population size, and CO_2 emissions are presented in Table 1.

Table 1. Descriptive Statistical Test Results

Descriptive	$logCO_2$	logGDPPC	HDI	logPOP
Mean	10.224	7.947	0.671	16.678
Median	10.685	7.745	0.665	17.189
Maximum	13.313	11.110	0.938	19.421
Minimum	5.122	4.875	0.419	12.7186
Std. Dev.	2.160	1.514	0.125	1.917
Skewness	-0.622	0.411	0.196	-0.613
Kurtosis	2.454	2.392	2.327	2.320
Sum	2341.329	1819.763	153.675	3819.241
Sum Sq. Dev.	1064.608	522.622	3.580	832.290
Obs.	229	229	229	229

Source: Authors' Estimation, 2024

Table 1 presents the results of descriptive statistical tests. The average CO_2 emissions were 10.224, with a median of 10.685 and a range from a minimum of 5.122 to a maximum of 13.313. The standard deviation of 2.160 indicates considerable variability in CO_2 emissions across the ASEAN countries studied. A negative skewness value of -0.622 suggests that the distribution of CO_2 emissions is skewed to the left, indicating more observations on the higher end of emissions. Regarding the independent variables, the log of GDP per capita has a mean of 7.947 and a standard deviation of 1.514, with a positive skewness of 0.422. This skewness indicates that GDP per capita tends to have more observations towards higher values. On the other hand, the log of population has a mean of 16.68, a standard deviation of 1.917, and a negative skewness of -0.613. This negative skewness suggests that the population data is skewed towards lower values. These findings underscore the wide variations in development levels and CO_2 emissions among ASEAN countries, highlighting the diverse economic and demographic landscapes across the region.

Table 2. Unit Root Test of Selected Dependent and Independent Variables

Variable	Statistic		Statistic	
	Level	Prob.**	First difference	Prob.**
Log CO_2	-0.773	0.219	-3.299	0.001
Log GDP	-4.978	0.000	-	-
HDI	-5,757	0.000	-	-
Log Pop	-2,062	0.021	-	-

Source: Authors' Estimation, 2024

Table 2 presents the results of the unit root test for the variables. The tests indicate that all four variables— GDP per capita, HDI, Population Size, and CO_2 Emissions—demonstrate stationary behavior. Specifically, GDP per capita, HDI, and Population Size are stationary in their level state, while CO_2 Emissions are stationary in the 1st difference. The statistically significant probability values, all below 0.05 ($p < 0.05$), confirm these findings. This implies that none of these variables exhibit a unit root, indicating that their statistical properties such as mean and variance remain constant over time. With this assurance of stationarity, we can proceed confidently with further analysis, such as regression modelling, knowing that the data are stable and suitable for such analytical methods.

This study employs panel data regression analysis, with model selection being the first step prior to analyzing the regression results. Three-panel data regression models are considered: the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM). To determine the most appropriate model among CEM, FEM, and REM, we perform the Chow Test, Hausman Test, and Lagrange Multiplier Test. Initially, the Chow Test is conducted to choose between CEM and FEM. The results of the Chow Test indicate a p-value of 0.000, which is less than the significance level of 0.05 ($\alpha = 0.05$). Consequently, FEM is selected as the appropriate model over CEM. Following this, the Hausman Test is conducted to determine the better model between FEM and REM. The Hausman Test results yield a p-value of 0.013, which is also less than 0.05. Thus, FEM is again identified as the appropriate model between FEM and REM. Additionally, the normality test results show a Jarque-Bera value of 0.336, which is greater than the significance level of 0.05. Therefore, it can be concluded that the data is normally distributed.

Based on the result the correlation matrix value of CO_2 emissions, human development index, and population is smaller than 0.80 so it can be concluded that there is no multicollinearity problem. In our analysis, we conducted a Likelihood Ratio (LR) test for heteroskedasticity and obtained a p-value of 0.730. Since this p-value is much greater than our chosen significance level of 0.05, we fail to reject the null hypothesis of homoskedasticity. This indicates that there is no statistically significant evidence of heteroskedasticity in our model, and thus, we can proceed with our current model without adjustments for heteroskedasticity.

We also conducted a test for cross-sectional dependence and obtained a chi-square value of 6.421 with a corresponding p-value of 0.000. Since the p-value is less than our chosen significance level of 0.05, we reject the null hypothesis of no cross-sectional dependence. This indicates strong evidence of cross-sectional dependence in our data. Consequently, we will adjust our model to account for this dependence to ensure the validity of our inference.

Table 3. Panel Data Regression Results with Fixed Effect Model

Dependent variable = logCO_2				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Constant	-6.993	6.773	-1.033	0.303
logGDPPC	0.469	0.095	4.959	0.000
HDI	1.982	1.619	1.225	0.222
logPOP	0.729	0.440	1.653	0.099
R^2	0.982			
F-statistic	903.308			
Model selection test	***F-test***	***Prob.***		
Chow test	279.838	0.000		
Hausman test	10.788	0.013		
LM test	783.424	0.000		
Diagnostics test	X^2	***Prob.***		
Pesaran CD test	6.421	0.000		
LR test	0.123	0.730		
Normality test	2.183	0.336		

Source: Authors calculation, 2024

Based on Tabel 3, our result shows that the intercept (β_0 = -6.993) means that when HDI, GDP per Capita, and population size are zero, the CO_2 emissions value will decrease by 6.99 percent. The Gross Domestic Product Per Capita coefficient is (β_1 = 0.469) meaning that an increase in GDP of 1 dollar will increase CO_2 emissions by 0.469 percent. The Human Development Index coefficient is (β_2 = 1.983) meaning that an increase in the Human Development Index (HDI) by one unit will cause CO_2 emissions to increase by 1.983. The population coefficient is (β_3 = 0.729) meaning that an increase in population by 1 person will increase CO_2 emissions by 0.729 percent in the air. It is also necessary to see R^2 which can predict how much variation in the independent variable can explain the dependent variable. From the Table 5, the customized R-square (R^2) is 0.982. This value means that the ability of the variables GDP per capita, HDI, and population size to explain variations in the production variable CO_2 emission is 98.2 percent, while the rest 2.8 percent is explained by other variables outside the variables used in this study model.

This interpretation provides an understanding of how changes in each independent variable (GDP per Capita, HDI, and population size) contribute to changes in the dependent variable (CO_2 emission) in the context of the multiple linear regression model. However, to get a correct conclusion, the interpretation results must be linked to F-test and t-test results. Based on the results of panel data analysis using the FEM, a simultaneous test of the independent variable on the dependent variable found that there is a simultaneous effect of the gross domestic product per capita (GDP per capita), human development index (HDI), and population size on CO_2 emissions in ASEAN. This is indicated by a Prob(F-stat) of 0,000 which is smaller than 0,05. This simultaneous influence means that efforts to improve human welfare are also accompanied by an increase in economic activity and population, which can lead to increased CO_2 emissions if not balanced with appropriate environmental policies.

The results of t-statistical tests carried out to determine the influence of the significance of each independent variable partially on the dependent variable, which is to have a significant effect, the t-statistical value of a variable must be smaller than the significance t value of 0,05. Partial test results using the FEM method show different effects of each variable.

The t-statistical significance value for GDP per capita is 0,000 < 0,05 which means that it has a significant effect on CO_2 emissions. In simple terms, an increase in GDP per capita represents an increase in income which increases demand for the number of goods and services. This will encourage increased production and increased consumption which will increase the amount of waste produced into the environment. The condition that occurs in developing countries, such as most countries in the ASEAN region, is by the Environmental Kuznet Curve hypothesis which states that initially as economic activity increases, the amount of CO_2 produced will increase and increase environmental damage, but environmental damage due to increasing Economic activity may not occur consistently in every economy in a country. The impact of increasing GDP per capita can have different impacts in different countries. However, in developing countries, such as most countries in the ASEAN region, the increase in GDP per capita, shows that economic development tends to always increase the amount of CO_2 emissions, one of which is due to developing countries, where renewable energy sources are not yet predominant. Most production processes in developing countries tend to experience high growth and are still very dependent on fossil fuels which produce higher amounts of CO_2 compared to renewable energy. Apart from that, circular economy activities that can reduce the amount of waste resulting from consumption are still very minimal. Thus, this is also due to the lack of knowledge and capability of human resources in developing countries such as most countries in ASEAN regarding sustainable development. For example, in Indonesia, data from the last five years shows that the growth and development of industry have resulted in the potential for large amounts of waste to be produced and this must be considered further so that it does not become a problem that could have a disastrous impact in the future.

Apart from that, income inequality between regions also has an impact on the inequality of CO_2 emissions produced. Urbanization and infrastructure expansion accompanying economic growth contribute significantly to CO_2 emissions through the construction and maintenance of roads, buildings, transportation networks, and other upgrading facilities. Increased energy demands for heating, cooling, and household appliances further escalate emissions. Continuing to rely heavily on fossil fuels despite technological advancements, while improving energy efficiency, also stimulates higher energy consumption and emissions. Empirical evidence consistently shows that countries with higher GDP per capita tend to exhibit higher CO_2 emissions. In Southeast Asia, where approximately 90% of primary energy consumption derives from fossil fuels (World Bank, 2023), this reliance exacerbates atmospheric CO_2 levels.

The significance value of the HDI t-statistic is 0,222 > 0.05, which means that HDI has not a significant effect on the production of CO_2 emissions. The results of the regression analysis show that HDI does not affect CO_2 emissions in ASEAN countries. This is because production in developing countries still depends on technology and infrastructure that is less efficient and not

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environmentally friendly. Limited access to environmentally friendly technology and renewable energy causes high CO_2 emissions despite an increase in HDI. Rapid urbanization in developing countries is not accompanied by careful planning and the availability of adequate infrastructure, causing energy use to increase rapidly without effective emissions management so that CO_2 emissions remain high. What is no less important is the low level of awareness and education about sustainable development issues in developing countries where most ASEAN countries are still low, usually focusing more on economic growth and industrialization as priorities to improve living standards, so that even though HDI increases, without adequate environmental education, society will not implement practices that can reduce CO_2. Environmental policies and regulations in developing countries are also not as good and strict as those in developed countries. Law enforcement and incentives for sustainable practices are often less effective, so CO_2 remains high.

Apart from that, developing countries tend to prioritize welfare development, but this is not accompanied by attention to efforts to reduce CO_2. Therefore, although HDI in developing countries can increase, it is not always followed directly by a decrease in CO_2 due to structural, economic, and policy factors that are different from developed countries. Aligned with findings from Rezeki & Islami (2022), short-run improvements in HDI may not significantly affect environmental pollution, but long-run improvements in HDI can influence consumption patterns and environmental decisions positively. Having a significant impact on the consequences, future challenges include sustaining HDI growth while curbing CO_2 emissions. Rather than reducing consumption, the focus should be on transitioning to renewable energy sources to meet increasing energy demands sustainably, thereby mitigating pollution.

The results of t-statistical tests for population is 0,099 > 0,5 which means that population size does not affect CO_2 produced in ASEAN countries. Even though the population continues to increase, it does not guarantee that this will affect the CO_2 produced. Although population is important, the effectiveness of environmental policies, the technology used, and changes in societal behavior play a very important role in determining CO_2 emissions. Therefore, population is not always the main factor if other factors are managed well. This is in line with the results of the study conducted by the Observer Research Foundation (2020) in Asia, Africa, America, North America, South America, and Oceania which found that increasing population does not necessarily increase CO_2 emissions, there is a complex interaction between geophysics and economics. A region is relevant to increasing CO_2 emissions.

These findings underscore the critical importance of integrating environmental considerations into development policies in ASEAN countries. Sustainable development strategies should prioritize investments in renewable energy, clean technologies, and environmentally friendly practices to harmonize economic growth with environmental preservation, besides also need to do more studies on economic and environmental. Governments and stakeholders play pivotal roles in promoting sustainability by educating the public on environmental conservation's importance and implementing policies that support a transition towards a low-carbon economy. Ultimately, balancing economic growth with environmental sustainability demands concerted efforts to decouple economic activities from fossil fuel dependence, fostering a path toward sustainable development and environmental stewardship.

Based on the t-test and regression coefficient obtained, it can be concluded that between the GDP per Capita, HDI, and population size, there is only GDP Per Capita significant effect on CO_2 emissions produced in ASEAN countries. In the context of ASEAN countries from 2000 to 2020, this study finds that among the GDP per capita, Human Development Index, and total population, only GDP per capita exhibited a significant positive impact on CO2 emissions. HDI and population size, while positively correlated with CO_2 emissions, did not achieve statistical significance. The noteworthy influence of GDP per capita on CO_2 emissions can be attributed to several interconnected factors. Higher GDP per capita is typically associated with increased economic activities and industrialization, both of which heavily rely on fossil fuels for energy, thereby intensifying CO_2 emissions. Rising GDP per capita signifies improved welfare, reflected in enhanced consumption across sectors like education, health, and living standards, further driving production demands and energy consumption.

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Conventional economic development has successfully stimulated economic growth by boosting income levels, thereby driving consumer demand and production while catalyzing technological and communication advancements. However, this progress often necessitates the exploitation of natural resources and the environment (Nguyen et al., 2023). Infrastructure and urban development frequently involve land conversion to generate immediate economic gains, leveraging public resources like rivers and air, which are often exploited without regard to long-run environmental impacts. As a result, emissions of greenhouse gases contain various emissions, one of which is CO_2 freely entering the atmosphere, perpetuating environmental degradation (Bilgili, 2021).

Carbon dioxide emissions are a major concern in global discussions. Increased concentration of CO_2 emissions in the atmosphere triggers the greenhouse effect, which is one of the main contributors to global climate change. Carbon dioxide gas is produced by various human activities, including burning fossil fuels for energy, deforestation, and industrial activities. Increasing CO_2 concentrations in the atmosphere cause an increase in the greenhouse effect, resulting in global warming and climate change (Bashir et al., 2019; Tran et al., 2024). Climate change has far-reaching impacts and has the potential to damage the environment, economy, and human health. Rising global temperatures, changing rainfall patterns, and increasing extreme weather events are some of the direct consequences of increasing CO_2 emissions. In this context, a study on CO_2 emissions is very urgent and important to carry out at this time, especially in developing countries such as most countries in the ASEAN region which have had an increasing CO_2 emissions trend in recent decades (Munir et al., 2020). Through a better understanding of the sources, impacts, and potential solutions to CO_2 emissions, we can take concrete steps to reduce emissions, develop effective policies, encourage technological innovation, increase public awareness, and ensure economic sustainability. Only with sustained and comprehensive study can we overcome the enormous challenges faced by climate change and safeguard the earth for future generations (Pata et al., 2023).

The study highlights that as ASEAN countries transition towards industrial economic structures, environmental sustainability often takes a backseat to economic priorities. Studies indicate that initial economic growth phases correlate with increased environmental degradation, although subsequent phases may exhibit stabilizing or reversing trends with sustainable policy interventions (Heidari et al., 2015;). This underscores the urgent need for policies promoting energy efficiency, investing in renewable energy sources, and enforcing emission regulations to mitigate environmental impacts (Bashir et al., 2021). The new challenge that needs to be faced is how to change the mindset of the government and society in most ASEAN countries from only achieving economic growth to achieving inclusive and sustainable economic growth.

4. CONCLUSIONS

This study reveals that while the Human Development Index and population size show a positive but statistically insignificant influence on CO_2 emissions in ASEAN countries, GDP per capita significantly impacts CO_2 emissions. This indicates that as GDP per capita rises, so does environmental strain in the ASEAN region. In light of these findings, governmental intervention is crucial to formulate policies that support economic growth while safeguarding the environment. Governments can play a pivotal role by promoting renewable energy resources, clean technologies, and infrastructure equipped with environmentally friendly technologies. By providing adequate support in these areas, governments can mitigate the environmental impact of economic growth. Furthermore, stricter regulations and policies geared towards sustainable development are essential. Designing effective incentives, such as carbon taxes or emission trading systems, can encourage businesses and individuals to adopt greener practices and reduce emissions. These economic incentives not only promote environmental responsibility but also stimulate innovation in sustainable technologies. Additionally, fostering cooperation among ASEAN countries is vital. Collaborative efforts in sharing technology, resources, and knowledge can facilitate collective action toward reducing global emissions, particularly within the ASEAN region, while advancing sustainable development goals. In summary, addressing the environmental consequences of economic growth in ASEAN countries requires a multifaceted approach involving robust policies, incentives for green practices, and regional cooperation. By aligning economic development with environmental sustainability, governments can achieve balanced and sustainable growth for the ASEAN region.

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