Efficient Vol 8 (2) (2025): 206-213 DOI: https://doi.org/10.15294/efficient.v8i2.19790

EFFICIENT

Indonesian Journal of Development Economics

https://journal.unnes.ac.id/sju/index.php/efficient

Determinants of Carbon Dioxide Emissions in ASEAN-5 From 2010-2022: Through Energy Transition

Filda Luthfiana✉

Development Economic Study Program, Faculty of Economics and Business, Universitas Negeri Semarang

Permalink/DOI: https://doi.org/10.15294/efficient.v8i2.19790

Submitted: December 2024; Revised: March 2025; Accepted: June 2025

Abstract

Economic activity and energy consumption are the main drivers of the increase in CO_2 emissions that trigger global climate change. This study analyzes the effect of GDP per capita, GDP per capita squared, renewable energy consumption, non-renewable energy consumption, and environmental taxes on CO_2 emissions in ASEAN-5 (Singapore, Malaysia, Thailand, Philippines, and Vietnam) for the period 2010-2022 using the FMOLS dynamic panel method. The results show that GDP per capita, renewable energy consumption, and non-renewable energy have a significant positive effect on CO_2 emissions, while environmental taxes and GDP per capita have a significant negative effect. This study supports the Environmental Kuznets Curve hypothesis in the long run. Policy recommendations include diversifying the low-emission economy, reducing non-renewable energy consumption, accelerating the adoption of renewable energy with incentives, and strengthening environmental taxes to encourage environmentally and human-friendly technologies.

Keywords: Carbon Dioxide Emissions, Environmental Taxes, Environmental Kuznets Curve hypothesis, FMOLS Analysis

How to Cite: Determinants of Carbon Dioxide Emissions in ASEAN-5 From 2010-2022: Though Energy Transition. (2025). Efficient: Indonesian Journal of Development Economics, 8(2), 206-213. https://doi.org/10.15294/efficient.v8i2.19790

✉ Correspondence Address :
Address: Gedung L2 Lantai 2 FE Unnes
Kampus Sekaran, Gunungpati, Semarang, 50229
E-mail : fildaluhfiana@students.unnes.ac.id

INTRODUCTION

Climate change has become a significant global issue due to human activities, such as fossil fuel combustion and deforestation. These activities have increased the concentration of greenhouse gases, including carbon dioxide (CO_2), which is the main driver of global warming. The impacts of global warming have been felt since the mid-20th century, including changes in weather patterns, sea level rise, and intensified natural disasters (Widyawati et al., 2021).

In the Southeast Asian region, particularly the ASEAN-5 (Indonesia, Malaysia, Thailand, Philippines and Vietnam), CO_2 emissions continue to increase in line with rapid economic growth, industrialization and urbanization. This increase poses a major challenge to the region's environmental and economic extinction (Damassa et al., 2018).

Despite this, global awareness of the importance of environmental conservation continues to grow. International environmental conferences such as the Stockholm Declaration (1972), the Montreal Protocol (1987), the Rio Earth Summit (1992), the Kyoto Protocol (1997), and the Paris Agreement (2015) have produced international agreements that demonstrate global commitment to reducing carbon emissions (Statistical Review Energy, 2021).

However, while many countries have begun efforts to improve environmental quality, greater change can only be achieved through global cooperation and sustained commitment. Changes in extreme weather patterns, such as increased heat, unpredictable seasons and rising sea levels, further emphasize the real impacts of global warming that have been ongoing since the mid- 20th century (IPCC, 2021).

The World Bank (2024) notes that carbon emissions in ASEAN-5 are reaching levels fueled by fossil energy dependence. For example, Indonesia is the largest emitter in the region, with emissions driven by the use of coal for power generation. However, some countries such as Singapore have started to implement more progressive green energy policies, although challenges in the clean energy transition remain large (Statistical Review Energy, 2021).

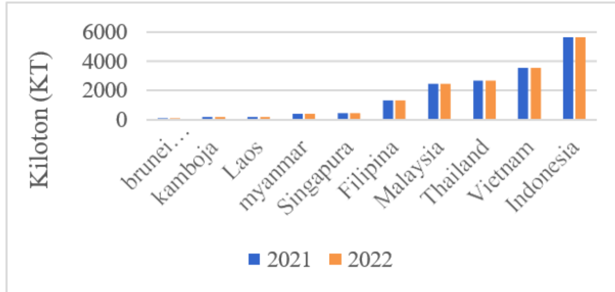

Figure 1. CO_2 Emissions in the ASEAN Region in 2021-2022

Source: World Bank, 2025

Figure 1 shows ASEAN CO2 emission data for 2021 and 2022, Indonesia is the largest contributor to CO2 emissions with 563,197 kilotons (kt) or about 563.2 megatons (Mt). Indonesia's high emissions are due to its significant reliance on fossil energy, especially coal, for power generation, as well as rapid urbanization and industrialization. In contrast, Brunei Darussalam has the smallest CO2 emissions in the region, at 9,588 kt. This is influenced by its small population, smaller economic scale and more focused emission control measures.

However, only the five countries selected for analysis - Singapore, Thailand, the Philippines, Vietnam and Malaysia - contribute significantly to ASEAN's total CO2 emissions. In 2021, Vietnam's emissions reached 355,323.1 kt, followed by Thailand, Malaysia, the Philippines and Singapore.

The increase in CO_2 concentration in the atmosphere is largely due to industrial processes, especially the burning of fossil fuels for energy purposes. The ASEAN region, particularly Indonesia and Vietnam, has been identified as a major contributor to CO_2 emissions in the region

(World Bank, 2020). Indonesia, with its rapidly growing economy, is the largest country in ASEAN with a high dependence on fossil energy. Meanwhile, Vietnam, which is also experiencing rapid economic growth, has seen a significant increase in carbon emissions due to its dominant use of fossil fuels (Statistical Review Energy, 2021).

In addition, the growing energy sector in these ASEAN countries is increasing the demand for energy, most of which is still sourced from fossil fuels. Therefore, policies to reduce dependence on fossil energy and develop renewable energy are increasingly important to reduce CO_2 emissions in the region (Damassa et al., 2018).

This research identified several key issues related to reducing CO_2 emissions in the ASEAN-5 region, which includes Indonesia, Malaysia, the Philippines, Vietnam and Singapore. One of the main challenges faced is the high dependence on fossil fuels to meet energy needs, which is a major constraining factor in reducing carbon emissions (Statistical Review Energy, 2021), while the transition to renewable energy is still constrained by various issues, including technological limitations, inadequate infrastructure and relatively high costs (IEA, 2020).

Environmental tax policies, designed to encourage the reduction of carbon emissions, are also still not optimized in the region (World Bank, 2021). Given these complexities, this research seeks to understand how economic factors and environmental policies play a role in reducing CO_2 emissions, with a focus on five selected ASEAN countries.

This study aims to explore the influence of economic factors and environmental policies on CO_2 emissions in the ASEAN-5 region. By analyzing the relationship between per capita income, energy consumption, and environmental tax policies, this research is expected to provide a deeper understanding of the dynamics of carbon emissions and how ASEAN countries can optimize their policies to significantly reduce emissions (International Monetary Fund, 2021).

More specifically, this research attempts to understand how economic growth as measured by GDP per capita affects carbon emissions in the region, as well as how energy consumption, both from renewable and non-renewable sources, contributes to emission levels (International Monetary Fund, 2021). It also analyzes the role of environmental tax policies in encouraging countries to take more responsibility for reducing carbon emissions (OECD, 2020).

This research is limited to analyzing data from five ASEAN countries, namely Indonesia, Malaysia, the Philippines, Vietnam and Singapore, over the period 2010 to 2022. This limitation was made to get a more specific picture of carbon emission conditions in countries with different economic and social characteristics.

However, this study does not differentiate between countries with different income levels, although there are significant differences between developed and developing countries in terms of GDP per capita M. F. Bashir et al. (2020). Therefore, further research could expand this analysis by separating developed and developing countries or extending the period of analysis to get a more complete picture of carbon emission changes in the long run.

Previous research shows that the Environmental Kuznets Curve (EKC) hypothesis is relevant for understanding the relationship between economic growth and environmental degradation. This hypothesis suggests that in the early stages of economic development, carbon emissions increase due to industrialization.

However, as per capita income increases, countries begin to adopt environmentally friendly technologies, so carbon emissions continue to decline (Grossman & Krueger, 1995).

However, the case of ASEAN shows that this pattern is not always linear. Some countries, such as Indonesia and Vietnam, face major challenges in balancing the needs of economic development and carbon emission reduction (Sharif et al., 2019).

In a policy context, the implementation of environmental taxes is one of the main strategies to reduce carbon emissions. These taxes aim to internalize the social costs of activities that pollute the environment, thereby encouraging the adoption of clean technologies and the reduction of fossil energy consumption (Pigou, 1920). However, the effectiveness of this policy in ASEAN is still limited due to differences in income levels, technological capacity, and development priorities in each country (Bashir et al., 2020).

This study aims to explore the determinants of CO_2 emissions in ASEAN-5 by integrating factors such as Gross Domestic Product (GDP) per capita, renewable and non-renewable energy consumption, and environmental taxes. Through a Fully Modified Ordinary Least Squares (FMOLS) approach, this study evaluates the long-term relationship between these variables over the period 2010-2022. This study is expected to contribute significantly to the literature and policies related to carbon emission reduction, especially in the ASEAN region.

RESEARCH METHODS

This type of research uses a quantitative approach. The location of this research study took the asean-5 region with a time span from 2010 to 2022. Due to the limitations of previous research and limited data availability, the author took a sample of five countries including malaysia, the philippines, thailand, singapore and vietnam.

This study aims to analyze the effect of gdp per capita, gdp per capita squared, renewable energy consumption, non-renewable energy consumption, environmental taxes on co_2 emissions. This study uses the fully modified ordinary least squares (fmols) method which processed the data using eviws 12 software.

This research utilizes the fully modified ordinary least squares (fmols) dynamic panel analysis method to process and analyze data. This method was introduced by phillips & hansen, (1990) and further developed by hsiao (2014). Fmols is based on the idea of estimating parameters using ordinary least squares (ols) by performing full modification on panel data that has a cointegration relationship.

Fmols is an extension of the ols method designed to overcome the problem of serial correlation or autocorrelation that arises due to endogeneity in the cointegration relationship. The presence of serial correlation can affect the estimates produced by ols, although in theory ols is the best linear unbiased estimator (blue) method based on the gauss-markov theorem.

In addition, endogeneity in the model estimated using ols may result in biased estimates. Therefore, fmols is designed to overcome these challenges, including controlling endogeneity, serial correlation, and heterogeneity among variables, so as to produce more consistent and reliable analysis (pedroni, 2000).

Fmols regression is an analytical tool that aims to provide an optimal analytical estimate of the long-run relationship in models that have cointegration in a regression. The fmols method aims to cover the weaknesses of biased and inconsistent models. The fmols analysis equation model is expressed as follows:

$$LogCO2 = \alpha_i + \beta_1 LogGDPc_{it} + \beta_2 LogGDPc^2 + \beta_3 LogNREC_{it} + \beta_4 LogREC_{it} + \beta_5 TAX_{it} + \mu_{it}$$

Where Log is logarithm; Co2 is carbon emission; Gdpc is gross domestic product; Gdpc2 is gross domestic product square; Nrec is non-reneweble energy consumption; Rec is renewable energy consumption; Tax is environmental tax; α is constants; $\beta 1 - \beta 5$ are coefficient; μ is standard error; I is cross section (5 Countries) and T is time series (2010-2022).

RESULTS AND DISCUSSION

The stationarity test is conducted to check the stability of the data over time. The unit root test results show that most variables such as $logco_2$ and lognrec are stationary at the i(0) level, while other variables show stationary properties after the first differentiation (i(1)). This indicates that some of the data may experience long-term trends that need to be considered in further analysis.

Furthermore, to see the existence of a long- term relationship between the variables in this study, a cointegration test was conducted. The cointegration test results using Kao's methodology show that there is a long-term relationship between CO_2 emissions and independent variables, such as GDP per capita, renewable energy consumption, non-renewable energy consumption, and energy taxes.

The FMOLS dynamic panel has a requirement that each variable must have cointegration. Variables are declared to have cointegration with each other if each variable has a long-term relationship (Gujarati & Porter, 2009). This study uses Kao's (1999) methodology to conduct the cointegration test. The estimation results show that each variable has cointegration with each other. This is indicated by the p-value which is less than 5% in all estimation results.

Table 1. Stationarity Test Result

Variable	IPS Results	
	Level I(0)	First Difference I(1)
LOGCO2	0.0005	0.0336
LOGGDPc	0.1337	0.0000
LOGNREC	0.0117	0.0067
LOGREC	0.2361	0.0000
TAX	0.9019	0.0006

Source: Data processed, 2025

The coefficient of determination test is used to measure the ability of the model to explain the dependent variable. explain the dependent variable. The coefficient of determination is expressed by the R-squared value which ranges from zero to one. If the R-squared value is close to 1, then the independent variables in the model have a good ability to explain the dependent variable.

Table 2. (Kao Residual Cointegration Test)

Kao-Test	t-Statistic	Prob.
RESID(-1)	-3.190731	0.0065

Source: Data processed, 2025

Conversely, if the R-squared value is close to zero, then the independent variables only have a very limited ability to explain the dependent variable.Based on the estimation results, it is known that the R-squared value is 0.748165. This indicates that 74% of the variation in carbon dioxide (CO_2) emissions can be explained by the independent variables, GDP per capita, GDP per capita squared, non-renewable energy consumption, renewable energy consumption, and environmental taxes.

The rest is explained by variations in other factors not included in the model. The t-statistic test is used to test the effect of each independent variable on the dependent variable partially. This test looks at the probability of each independent variable.

Table 3. Fmols Analysis Regression

Dependent Variable: LogCO2				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LOG(GDPC)	0.998398	0.027934	3.574.090	0.0000
LOG(GDPC 2)	- 0.374130	0.070106	- 5.336.645	0.0000
LOG(NREC)	0.782523	0.215493	3.631.316	0.0006
LOG(REC)	0.929415	0.053229	1.746.059	0.0000
TAX	- 0.321304	0.076861	- 4.180.299	0.0001
R-squared	0.765238			
Adjusted R-squared	0.748165			

Source: Data processed, 2025

If the probability (p-value) is smaller than the real level of 5% (α = 0.05), then the independent variable has a significant effect on the dependent variable. Conversely, if the probability (p-value) is greater than 5%, the independent variable does not have a significant effect. Based on the estimation results of the FMOLS model, the resulting regression equation is:

$$LogCO2 = 0.998398\text{Log}GDPc_t - 0.374130\text{Log}GDPc2_t + 0.782523\text{Log}NREC_t + 0.929415\text{Log}REC_t - 0.321304TAX_t$$

GDP per capita has a coefficient of 0.998398 with a probability value of 0.00, less than the significant value of 0.05. This indicates that a one percent increase in GDP per capita will significantly affect carbon emissions by 0.998 percent assuming ceteris paribus. GDP per capita squared has a coefficient of -0.374130 and a probability value of 0.0000, less than the significant value of 0.05. This indicates that a one percent increase in GDP per capita squared will significantly affect carbon emissions by 0.374 percent, assuming ceteris paribus.

Non-renewable energy consumption has a coefficient of 0.782523 with a probability of 0.006 less than the significant value of 0.05. This shows that non-renewable energy consumption increases by one percent will significantly affect carbon emissions by 0. 782 percent with ceteris paribus assumptions. Renewable energy consumption has a coefficient of 0.929415 with a probability of 0.00, less than the significant value of 0.05. This shows that an increase of one percent in renewable energy consumption will significantly affect carbon emissions by 0. 929 percent with ceteris paribus assumption. Environmental tax has a negative coefficient of -

0.321304 with a probability of 0.0001 less than a significant value of 0.05. This shows that an increase of one percent in environmental tax will significantly affect carbon emissions by 32 percent with the assumption of ceteris paribus.

The wald test is used to facilitate the FMOLS panel regression method in knowing the F test. if the probability value on the F statistic < alpha, then H_0 is rejected and H_a is accepted. This means that the independent variables jointly affect the dependent variable.

Table 4. Wald test

Test Statistic	Value	Df	Probability
F-statistic	6.648.977	(5, 55)	0.0000
Chi-square	33244.89	5	0.0000

Source: Data processed, 2024

Based on table 4 shows that the results of the wald test obtained an F statistic probability of 0.0000 <5% alpha, it can be concluded that H_0 is rejected and H_a is accepted. This means that overall the independent variables together have an effect on the dependent variable.

CONCLUSION

Economic growth has two forms of influence, namely a significant positive and significant negative effect on carbon dioxide emissions in ASEAN-5 in the long run. This proves that the EKC hypothesis is proven in ASEAN-5 using the CO_2 emission proxy. Non-renewable energy consumption has a positive and significant effect on carbon dioxide (CO_2) emissions in ASEAN-5. ASEAN-5's dependence on fossil fuels is the main cause of high carbon emissions, reflecting the urgent need for energy transition to cleaner sources. Renewable energy consumption has a positive and significant effect on carbon dioxide (CO_2) emissions in ASEAN-5.

However, the impact is not large enough to fully reduce emissions. This reflects that the application of renewable energy still needs to be increased to achieve a more significant carbon reduction target. Environmental taxes have a negative and significant effect on carbon dioxide (CO_2) emissions in ASEAN-5. This suggests that fiscal policies directed at reducing carbon emissions, such as environmental taxes, are effective in supporting environmental quality. However, the effectiveness of these policies is still affected by the sustainability of implementation and monitoring.

REFERENCES

Allard, A., Takman, J., Uddin, G. S., & Ahmed, A. (2018). The N-shaped environmental Kuznets curve: an empirical evaluation using a panel quantile regression approach. *Environmental Science and Pollution Research*, *25*(6), 5848–5861. https://doi.org/10.1007/s11356-017-0907-0

Bashir, A., Susetyo, D., Suhel, S., & Azwardi, A. (2021). Relationships between Urbanization, Economic Growth, Energy Consumption, and CO2 Emissions: Empirical Evidence from Indonesia. *Journal of Asian Finance, Economics and Business*, *8*(3), 79–90. https://doi.org/10.13106/jafeb.2021.vol8.no3. 0079

BP Statistical Review Energy. (2021). Statistical Review of World Energy globally consistent data on world energy markets and authoritative publications in the field of energy. *BP Energy Outlook*, *70*, 72. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Coase, R. H. (2012). The Problem of Social Cost. *The Journal of Law & Economics*, *56(4)*, 837– 877. https://doi.org/10.1086/674872

Damassa, T., Fransen, T., Haya, B., Ge, M., Jeczka, K. P., & Ross, K. (2018). Menginterpretasikan INDC: Menilai Transparansi Target Emisi Gas Rumah Kaca Pasca-2020 Dari 8 Negara Penyumbang Emisi Terbesar.

World Resources Institute, 1–11. https://wri-indonesia.org/

Grossman, G. M., & Krueger, A. B. (1966). Economic Growth and the Individual. *The Journal of Finance*, *21*(3), 550. https://doi.org/10.2307/2977834

Gujarati, D. N. (1972). Basic Econometrics Fourth Edition. In A. Bright (Ed.), *The Economic Journal* (Vol. 82, Issue 326). McGraw-Hill Companies. https://doi.org/10.2307/2230043

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53–74. https://doi.org/10.1016/S0304- 4076(03)00092-7

IPCC Panel. (2014). *Climate Change 2014: Synthesis Report*. 1–151.

IPCC Panel. (2021). *Climate Change 2014: Synthesis Report*. 1–151

Osobajo, O. A., Otitoju, A., Otitoju, M. A., & Oke, A. (2020). The impact of energy consumption and economic growth on carbon dioxide emissions. *Sustainability (Switzerland)*, *12*(19), 1–16. https://doi.org/10.3390/SU12197965

Pedroni, P. (2000). Fully Modified Ols for Heterogeneous Cointegrated Panels. In Nonstationary Panels, Panels Cointegration, and Dynamic Panels. *Nonstationary Panels, Panel Cointegration and Dynamic Panels*, *15*, 93–130. https://pdfs.semanticscholar.org/b6b4/fe66e3344b173e4cd91c9ec768296c2e4fbf.pdf

Pigou, A. C. (1920). The Economics of Welfare. *The Economic Journal*, *31*(122), 206. https://doi.org/10.2307/2222816

Phillips, P. C. B., & Hansen, B. E. (1990). Statistical inference in instrumental variables regression with i(1) processes. *Review of Economic Studies*, 57(1), 99–125. https://doi.org/10.2307/2297545

Energy Reports, *9*, 1384–1391. https://doi.org/10.1016/j.egyr.2023.05.185

Sugiyono. (2016). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Alfabeta.

Sharif, A., Raza, S. A., Ozturk, I., & Afshan, S. (2019). The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: A global study with the application of heterogeneous panel estimations. Renewable Energy, 133, 685–691. https://doi.org/10.1016/j.renene.2018.10.05 2

Widyawati, R. F., Hariani, E., Ginting, A. L., & Nainggolan, E. (2021). Pengaruh Pertumbuhan Ekonomi, Populasi Penduduk Kota, Keterbukaan Perdagangan Internasional Terhadap Emisi Gas Karbon Dioksida (CO2) Di Negara ASEAN. Jambura Agribusiness Journal, 3(1), 37–47. https://doi.org/10.37046/jaj.v3i1.11193