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Analysis of the Impact of Economic Growth and Deforestation Rates on Carbon Dioxide Emissions in Indonesia

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Abstract

Indonesia faces the challenge of maintaining a balance between economic growth and environmental sustainability, particularly regarding rising carbon dioxide (CO_2) emissions. However, studies that simultaneously integrate the effects of economic growth and deforestation rates on carbon emissions remain relatively limited. This study aims to address this gap by analyzing the effects of economic growth and deforestation rates on CO_2 emissions in Indonesia. Using annual time-series data from 2004 to 2023, this study applies the Error Correction Model (ECM) approach to evaluate the short-term and long-term relationships among the variables. The results indicate that, individually, economic growth and deforestation rates do not have a significant effect on CO_2 emissions in either the short or long term. However, when considered simultaneously, both variables have a significant long-term impact on CO_2 emissions. These findings suggest that carbon emission dynamics in Indonesia are influenced not only by economic activities and land-use changes but also by other factors outside the model. This study offers important implications for the government in formulating sustainable development policies, particularly through deforestation control and the strengthening of the transition to environmentally friendly energy.

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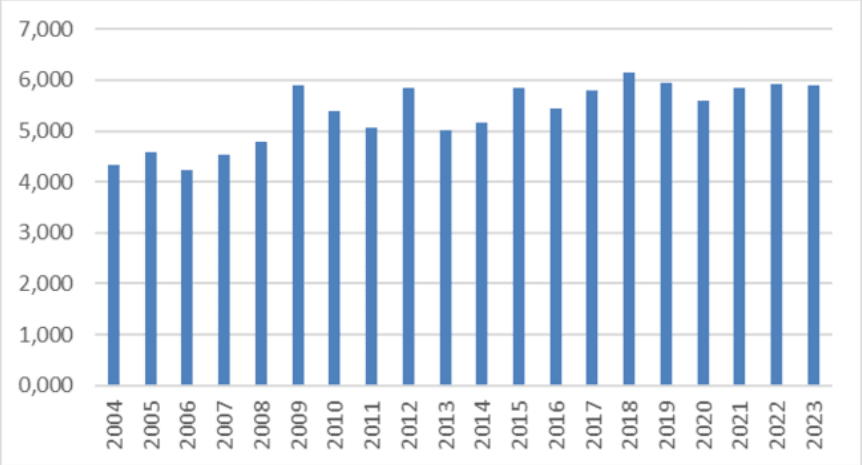
INTRODUCTION

Economic growth is a key indicator for assessing a country's development success, as reflected in increases in Gross Domestic Product (GDP) and the well-being of its people (Gajdosova, 2023). From a development economics perspective, sustainable economic growth is expected to improve the quality of life through increased income, employment opportunities, and productive activities (Rajnoha, 2021). However, economic growth that is not accompanied by sustainable management of natural resources has the potential to cause negative externalities in the form of environmental degradation. Increased economic activity, industrialization, and the use of fossil fuels are the main factors driving the rise in carbon dioxide (CO_2) emissions, which is one of the primary greenhouse gases contributing to global climate change (Tariqur et al., 2024).

In the context of Indonesia's economic development, the relatively stable economic growth of the past few decades has been followed by an increase in energy production and consumption (Jumono et al., 2021). This situation indirectly increases pressure on the environment, particularly through rising CO_2 emissions. In addition, Indonesia also faces significant environmental challenges, one of which is the high rate of deforestation resulting from the conversion of forests into agricultural land, plantations, and infrastructure development (Austin et al., 2019). Deforestation leads to a reduction in forest cover, which acts as a carbon sink; consequently, it not only reduces carbon sequestration capacity but also increases carbon emissions through the release of carbon stored in forest biomass (Maulida et al., 2025)

Figure 1.Carbon Dioxide (CO2) Emissions in Indonesia, 2004–2023



Source: World bank, processed by author

As shown in Figure 1, carbon dioxide (CO2) emissions in Indonesia from 2019 to 2023 fluctuated but generally followed an upward trend (World Bank, 2023). In 2019, the graph showed an increase, marking the year with the highest carbon dioxide (CO_2) emissions in Indonesia; however, in 2020, emissions declined due to the COVID-19 pandemic. However, in the following years, carbon dioxide (CO_2) emissions rose again as economic activity recovered, indicating that pressure on the environment continues.

The main issue in this study is the persistently high level of carbon dioxide

emissions in Indonesia, which has shown an upward trend over time, despite the implementation of various environmental control policies. This situation reflects an imbalance between economic development activities and environmental conservation efforts. Therefore, an empirical study is needed to identify the key factors influencing the rise in carbon emissions, particularly those related to economic growth dynamics and land-use changes

A number of previous studies have examined the relationship between economic growth, deforestation rates, and carbon dioxide (CO_2) emissions. A study conducted by (Begum & Raihan, 2020) analyzing the effects of economic growth and forest area on carbon dioxide (CO_2) emissions in Malaysia. The results of the study indicate that economic growth has a positive and significant effect on carbon dioxide (CO_2) emissions, while forest area has a negative and significant effect. This suggests that increased economic activity drives higher carbon emissions, while the presence of forests plays a crucial role as carbon sinks; consequently, deforestation can exacerbate the rise in carbon emissions.

Research by (Mariola Piłatowska, 2020) indicates that economic growth has a positive impact on CO_2 emissions, particularly during the economic expansion phase. In addition, nuclear energy has been shown to reduce emissions, whereas renewable energy has not yet had a significant impact. However, the increase in economic activity, which remains dependent on fossil fuels, means that emissions reductions have not yet been fully realized, and thus the decoupling of economic growth from carbon emissions has not yet been achieved.

Further research (Arifin et al., 2023) indicates that economic growth has a positive and significant impact on carbon dioxide (CO_2) emissions in Indonesia. The research results indicate that economic growth contributes approximately 39.77% to the increase in carbon emissions. These findings suggest that during the early stages of development, increased economic activity is still dominated by the use of fossil-based energy, thereby increasing carbon emissions; however, in the long term, there is potential for a reduction in emissions as energy efficiency improves and the use of environmentally friendly technologies increases.

Although these various studies have made important contributions, there are still discrepancies in the research findings, indicating inconsistencies. Furthermore, most previous studies have primarily focused on the impact of economic growth on carbon dioxide (CO_2) emissions, while studies that simultaneously examine the role of deforestation rates remain relatively limited. Therefore, further research is needed to comprehensively assess the combined effects of economic growth and deforestation rates on carbon dioxide (CO_2) emissions in Indonesia.

The relationship between economic growth, deforestation rates, and carbon dioxide (CO_2) emissions shows a strong correlation (Begum & Raihan, 2020). Increased economic growth tends to drive an increase in energy production and consumption, which ultimately contributes to higher carbon emissions (Taheri & Akadiri, 2019). On the other hand, the high rate of deforestation reduces the forest's capacity to act as a carbon sink, thereby increasing the amount of carbon released into the atmosphere (Houghton & Nassikas, 2018). Thus, economic growth and the rate of deforestation together play a role in influencing carbon dioxide (CO_2) emissions (Fattah & Fanny Nailufar, 2025).

Within this framework, this study empirically examines how economic growth and deforestation rates influence carbon

dioxide (CO_2) emissions in Indonesia during the observation period of 2004–2023. This study is expected to provide a more comprehensive understanding of the relationship between economic activity, land-use change, and environmental pressure. Through a quantitative analysis approach, this study aims to address gaps in the existing literature, particularly regarding studies that simultaneously link economic growth and deforestation rates to carbon dioxide (CO_2) emissions in the Indonesian context. Thus, this research is expected not only to contribute to the advancement of knowledge in the field of environmental economics but also to generate relevant policy recommendations to support sustainable development and carbon emission control in Indonesia.

Economic Growth

Economic growth is an increase in a country's production capacity, as reflected in the rise in Gross Domestic Product (GDP) over the long term (Auxiliadora et al., 2024). According to the classical theory proposed by Adam Smith, economic growth is influenced by the accumulation of capital, labor, and technological progress (Smith, 2007). Furthermore, in Robert Solow's neoclassical theory, economic growth is explained by the combination of capital, labor, and technology as the primary factors determining a country's output (Solow, 1956). In the modern context, economic growth is often associated with increased industrial activity and energy consumption, which can lead to higher carbon dioxide (CO_2) emissions (Dian Priastiwia, 2026). Therefore, economic growth has a complex relationship with the environment, particularly in terms of increased carbon emissions

Environmental Kuznets Curve (EKC)

The relationship between economic growth and carbon dioxide (CO_2) emissions can be explained using the concept of the Environmental Kuznets Curve (EKC) (Khan & Ullah, 2019). This concept states that in the early stages of development, increased economic growth tends to be accompanied by increased environmental damage, including carbon emissions, due to high levels of industrial activity and the exploitation of natural resources. However, as income and environmental awareness rise, and with the support of technological advancements and more environmentally friendly policies, carbon emissions can decrease (Dogan et al., 2022). Thus, the relationship between economic growth and carbon dioxide emissions follows an inverted U-shaped curve. In the context of Indonesia as a developing country, increased economic growth that has not yet been fully offset by the use of clean technologies and optimal environmental management has the potential to lead to an increase in carbon dioxide emissions (Nadira Fitri Arifiyah, 2025).

Deforestation

Deforestation is the conversion of forest cover into non-forest land as a result of human activities such as agriculture, plantations, and infrastructure development (Ramadhan, 2025). According to the environmental economics approach, deforestation occurs due to economic pressures to use forest land to increase short-term economic value (Amalia Subha Pratiwi & Pravitasari, 2024). This theory explains that unsustainable economic growth can lead to excessive exploitation of forests. Indonesia, as a country with vast tropical forests, faces significant deforestation issues, primarily due to the expansion of oil palm plantations and logging activities (Rahmawati A. Damiti et al., 2025). Deforestation contributes significantly to rising CO_2 emissions because it reduces forests' ability to absorb carbon (carbon sink).

Carbon dioxide (CO_2) emissions

Carbon dioxide (CO_2) emissions are one of the primary causes of global climate change. From an environmental economics perspective, human activities such as the burning of fossil fuels, industrial processes, and deforestation are the main sources of CO_2 emissions (Fattah & Fanny Nailufar, 2025). According to the greenhouse effect, rising CO_2 concentrations in the atmosphere trap Earth's heat, thereby increasing global temperatures (Ulum, 2025). This theory

emphasizes the importance of sustainable management of natural resources and the control of emissions through environmental policies, such as the use of renewable energy and forest conservation.

RESEARCH METHODS

Data

In this study, the researchers used secondary time-series data in annual form from 2004 to 2023. The data were obtained from official sources relevant to the study variables, thereby providing an accurate picture of economic growth, deforestation rates, and carbon dioxide (CO_2) emissions in Indonesia during the observation period (Word Bank, 2023).

The data collection technique used is the documentation method, which involves the process of collecting, recording, and presenting data in numerical form sourced from official publications. This method is commonly used in quantitative research because it allows for the use of existing and verified data (Sugiyono, 2019). For the purposes of this study, the researchers collected data related to the variables under investigation—namely, economic growth, deforestation rates, and carbon dioxide (CO_2) emissions which were obtained from the World Bank and Our World in Data.\

This study uses two independent variables economic growth and deforestation rate and one dependent variable carbon dioxide (CO_2) emissions. Further details regarding these variables, their operational definitions, measurement instruments, and data sources are provided in the following table.

Table 1. Table Operation

No.	Variables	Indicators/Estimation Instruments	Sources
1.	Emisi CO_2 (Y_1)	Emissions per capita = $\frac{Total\ CO2\ Emission}{Total\ Population}$	World Bank
2.	Economic Growth (X_1)	Economic Growth (%) $=\left(\frac{GDP_t - GDP_{t-1}}{GDP_{t-1}}\right)$ x 100%	World Bank
3.	Deforestation Rate (X_2)	Percentage=$\left(\frac{Area\ of\ Forest\ Lost}{Original\ Forest\ Area}\right)$ x 100%	World Bank

Source: Data compiled from previous research (2025)

Data Analysis Techniques

The data analysis technique used in this study is time series analysis using the Error Correction Model (ECM) approach to determine the short-term and long-term relationships between economic growth, deforestation rates, and carbon dioxide (CO_2) emissions. Data processing was performed using EViews 12 software. Prior to estimating the ECM model, stationarity and cointegration tests were conducted to ensure that the data met the requirements for time series analysis. Subsequently, the ECM model was estimated to examine long-term equilibrium and short-term adjustment mechanisms. Hypothesis testing was performed to determine the significance of the independent variables' effects on the dependent variable, thereby enabling the research findings to empirically explain the causal relationships among the variables.

RESULT AND DISCUSSION

The data analysis in this study was conducted using the Error Correction Model (ECM) approach to identify the short-term

and long-term relationships between economic growth, deforestation rates, and carbon dioxide (CO_2) emissions in Indonesia. Prior to estimating the ECM model, a series of preliminary tests were conducted, including stationarity and cointegration tests. This test aims to ensure that the data used meets the requirements for time series analysis and exhibits a long-run equilibrium relationship. Once all preliminary steps have been completed, an ECM model is estimated to analyze the relationships among variables more comprehensively. This analysis uses annual data from 2004 to 2023, and the results of the data processing are presented as follows.

Table 1 Results of Descriptive Analysis for Indonesia, 2004–2020

	Economic Growth(X1)	**Deforestation Rate (X2)**	**CO_2 Emission (Y_1)**
Mean	5,174850	415,3634	5,363600
Median	5,122000	401,3975	5,510000
Maximum	6,345000	757,1070	6,157000
Minimum	2,066000	177,3590	4,231000
Std. Dev.	0,967172	185,9801	0,604358

Source: Data processed by author (2025)

Descriptive Statistics

From Table 2. The analysis results show that economic growth has an average of 5,174850, with a minimum value of 2,066000 and a maximum of 6,345000, reflecting relatively stable conditions despite fluctuations. The deforestation rate has an average of 415,3634 with a range of values between 177,3590 and 757,1070, which is high. Meanwhile, carbon dioxide (CO_2) emissions averaged 5,363600, with a minimum value of 4,231000 and a maximum value of 6,157000, indicating an upward trend during the study period. The standard deviation indicates that the deforestation rate exhibits the highest level of fluctuation compared to the other variables. Overall, the research data exhibits sufficient variation for further analysis.

ECM (Error Correction Model) Data Analysis

The Error Correction Model (ECM) is used to analyze short-run and long-run relationships among variables in non-stationary but cointegrated time series data. This model also serves to correct short-run imbalances toward long-run equilibrium. Prior to estimating the ECM, a stationarity test is conducted as an initial step

1. Testing for Stationarity of the Data

Based on the test results in Table 3, the economic growth and deforestation rate variables are stationary at the first-difference level, with probability values of 0,0029 and 0,0000, respectively. Meanwhile, the CO_2 emissions variable is stationary at the second-difference level, with a probability value of 0,0000.

These results indicate that all variables are non-stationary at the original level but become stationary after the differentiation process. Thus, the data meet the requirements to proceed to the cointegration test in the ECM analysis.

Table 3 Stationary Test

Variables	*t-stat*	*Prob*	Level	Decision
Economic Growth (X1)	-4,51	0,0029	*First*	Stasioner
Deforestation Rates (X4)	-7,31	0	*First*	Stasioner
Carbondioxide Emission (Y1)	-7,698	0	*Second*	Stasioner

Source: Data processed by author (2025)

2. Data Integration Test

In this study, the cointegration test was conducted using the Engle-Granger method, specifically by testing the stationarity of the residuals from the long-run regression estimates using the Augmented Dickey-Fuller (ADF) test. Based on Table 4, the ADF probability value.

The value of 0.0114 is smaller than the significance level of 0.05, so the residuals (error correction term) are deemed stationary at this level. This indicates that there is a cointegration relationship between the variables of economic growth (X1), deforestation rate (X2), and CO_2 emissions (Y). Thus, it can be concluded that the three variables have a long-run equilibrium relationship, so the Error Correction Model (ECM) can be used to analyze both short-run and long-run relationships in this study

Table 4 Cointegration Test

	Level	*t-Statistic*	*Prob.**
ADF test statistic		-3,768169	0,0114
Test critical values	1% level	-3,831511	
	5% level	-3,029970	
	10% level	-2,655194	

Source: Data processed by author (2025)

3. Short-Run Regression Test

Based on Table 5, the ECM estimation results show that the error correction term (ECT) coefficient is -0.801222, with a p-value of 0.0176, which is less than 0.05 and negative. This indicates that the ECM model is valid and that there is an adjustment mechanism toward long-run equilibrium. This coefficient value indicates that approximately 80.12% of the short-run imbalance will be adjusted toward long-run equilibrium within one period

Meanwhile, the economic growth variable (X1) has a probability value of 0.7377 and the deforestation rate (X2) has a value of 0.1251, both of which are greater than 0.05. This indicates that, in the short term, economic growth and the deforestation rate do not have a significant effect on carbon dioxide (CO_2) emissions.

Table 5 ECM Estimation Result (Short-Term)

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	0,008896	0,097995	0,090782	0,9290
Economic Growth (X_1)	-0,038726	0,113195	-0,342115	0,7377
Deforestation Rates (X_2)	0,000893	0,000545	1,639217	0,1251
EC(-1)	-0,801222	0,295009	-2,715923	0,0176

Source: Data processed by author (2025)

4. Long-Run Regression Model Test

Based on Table 6, the adjusted R-squared value of 0.615632 indicates that the variables of economic growth and deforestation rate account for 61.56% of the variation in CO_2 emissions, while the remainder is explained by other variables outside the model. Simultaneously, the model has a significant F-statistic probability value (Prob < 0.05), indicating that the independent variables collectively influence CO_2 emissions in the long term.

However, in the partial analysis, the economic growth variable (X1) has a p-value of 0.8211, and the deforestation rate (X2) has a p-value of 0.3535, both of which are greater than 0.05. This indicates that, in the long run, neither variable has a significant effect on CO_2 emissions.

Table 6 ECM Estimation Result (Long Run)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1,661783	2,173407	-0,764598	0,4564
Economic Growth (X_1)	0,026964	0,117196	0,230074	0,8211
Deforestation Rate (X_2)	0,000652	0,000681	0,957548	0,3535
R-squared	0,696551	**Mean dependent var**		5,363600
Adjusted R-squared	0,615632	**S.D. dependent var**		0,604358
S.E. of regression	0,374687	**Akaike info criterion**		1,086864
Sum squared resid	2,105850	**Schwarz criterion**		1,335797
Log likelihood	-5,868641	**Hannan-Quinn criter**		1,135458
F-statistic	8,607942	**Durbin-Watson stat**		1,780918
Prob (F-statistic)	0,000812			

Source: Data processed by author (2025)

5. Test of Classical Assumptions

a. Results of the Multicollinearity Test

Based on Table 7, the correlation coefficient between the economic growth variable (X1) and the deforestation rate (X2) is -0,419963. Since this value is less than 0,8,

it can be concluded that there is no multicollinearity in the regression model. Thus, the model satisfies one of the classical assumptions and is suitable for further analysis.

Table 7 Result of the Multicollinearity Test

Variables	Economic Growth (X3)	Deforestation Rates (X2)	CO_2 Emission
Economic Growth (X1)	1,000000		
Deforestation rates (X2)	-0,419963	1,000000	
CO_2 Emission (Y1)	-0,358375	0,641906	1,000000

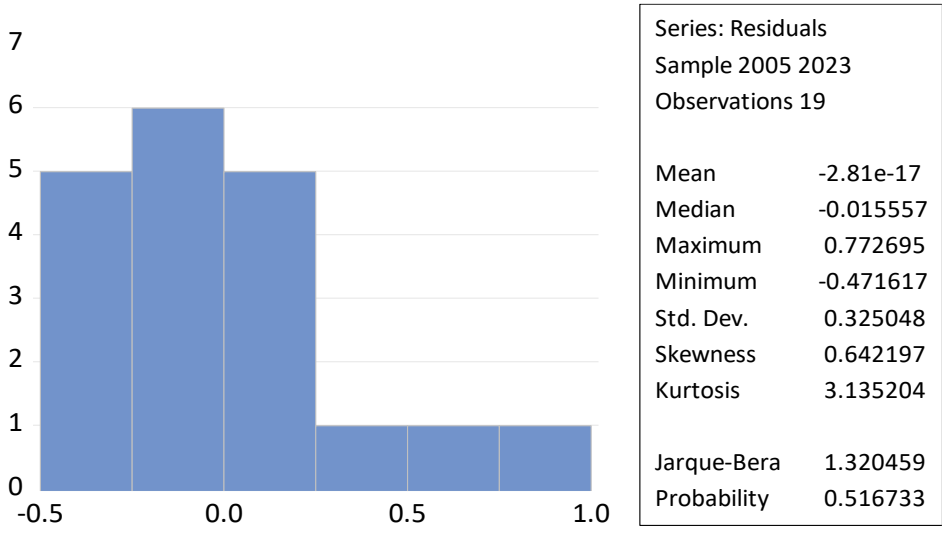
Source: Data processed by author (2025)

b. Normality Test Results

Based on the test results, a probability value of 0.516 was obtained, which is greater than 0.05. This indicates that the residuals in the regression model used to relate the economic growth variable (X1).

The rate of deforestation (X2) and carbon dioxide emissions (Y) are normally distributed. Thus, the regression model satisfies one of the classical assumptions and is therefore suitable for further analysis in this study.

Figure 2 Result of Normality Test



Source: Data processed by author (2025)

c. Autocorrelation Test Results

Based on the test results in Table 8, the observed R-squared value is 0,9775, which is greater than 0,05. This indicates that there is no indicates that there is no multicollinearity in the regression model. Thus, the model satisfies one of the classical assumptions and is suitable for further analysis.

There is an issue of autocorrelation in the regression model linking the variables of economic growth (X1), deforestation rate (X2), and carbon dioxide emissions (Y). Thus, the model satisfies the classical assumptions and is suitable for further analysis.

Table 8 Autocorrelation Test Result

Breush-Godfrey Serial Correlation LM Test:			
Obs*R-squared			
F-statistic	0,013188	***Prob. F(2,11)***	0,9869
Obs*R-squared	0,045450	***Prob. Chi-Square(2)***	0,9775

Source: Data processed by author (2025)

d. Result of the Heteroscedasticity Test

Based on Table 9, the probability value of the observed R-squared (Obs*R-squared) is 0,5921, which is greater than 0,05; therefore, it can be concluded that there is no heteroscedasticity in the regression model.

Thus, the model linking the variables of economic growth (X1), deforestation rate (X2), and carbon dioxide emissions (Y) satisfies the classical assumptions and is suitable for further analysis.

Table 9 Result of Heteroscedasticity Test

Breush-Godfrey Serial Correlation LM Test:			
Obs*R-squared			
F-statistic	0,013188	**Prob. F(2,11)**	0,9869
Obs*R-squared	0,045450	**Prob. Chi-Square(2)**	0,9775

Source: Data processed by author (2025)

6. Statistical Test

a. Partial Test (T-Test)

According to Table 10, the variables for economic growth (X1) and deforestation rate (X2) have p-values greater than 0,05 and therefore do not have a significant effect on carbon dioxide emissions (Y).

And thus do not have a significant effect on carbon dioxide emissions (Y). Therefore, taken individually, neither of the two independent variables has a significant effect on Y

Table 10 Result of the Partial Test (T-Test)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1,661783	2,173407	-0,764598	0,4564
Economic Growth (X_1)	0,026964	0,117196	0,230074	0,8211
Deforestation rate (X_2)	0,000652	0,000681	0,957548	0,3535

Source: Data processed by author (2025)

b. Simultaneous Test (F-Test)

Based on Table 11, the p-value for the F-statistic (0,000812) is less than 0,05; therefore, it can be concluded that economic growth (X1) and the rate of deforestation (X2) simultaneously have a significant effect on CO_2 emissions (Y).

Table 11 Result of Simultaneous Test (F-Test)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1,661783	2,173407	-0,764598	0,4564
Economic Growth (X_1)	0,026964	0,117196	0,230074	0,8211
Deforestation rate (X_2)	0,000652	0,000681	0,957548	0,3535
R-squared	0,696551	**Mean dependent var**		5,363,600
Adjusted R-squared	0,615632	**S.D. dependent var**		0,604358
S.E. of regression	0,374687	**Akaike info criterion**		1,086,864
Sum squared resid	2,105850	**Schwarz criterion**		1,335797
Log likelihood	-5,868641	**Hannan-Quinn criter.**		1,135458
F-statistic	8,607942	**Durbin-Watson stat**		1,780918
Prob(F-statistic)	0,000812			

Source: Data processed by author (2025)

c. Coefficient of Determination (R^2)

The adjusted R-squared value of 0.615632 indicates that the variables of economic growth (X1) and deforestation rate (X2) are able to explain the variation in emissions carbon dioxide (Y) accounts for 61.56%, while the remaining 38.44% is explained by other variables outside the research model.

Table 12 Coefficient of Determination (R^2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1,661783	2,173407	-0,764598	0,4564
Economic Growth (X1)	0,026964	0,117196	0,230074	0,8211
Deforestation rate (X2)	0,000652	0,000681	0,957548	0,3535
R-squared	0,696551	**Mean dependent var**		5,363600
Adjusted R-squared	0,615632	**S.D. dependent var**		0,604358
S.E. of regression	0,374687	**Akaike info criterion**		1,086864
Sum squared resid	2,105850	**Schwarz criterion**		1,335797
Log likelihood	-5,868641	**Hannan-Quinn criter.**		1,135458
F-statistic	8,607942	**Durbin-Watson stat**		1,780918
Prob(F-statistic)	0,000812			

Source: Data processed by author (2025)

Discussion

The results of the study indicate that, in the short term, economic growth does not have a significant impact on CO_2 emissions; however, in the long term, it has a positive impact on CO_2 emissions. This suggests that increased economic activity over the long term is still accompanied by increased consumption of fossil fuels, which leads to higher carbon emissions.

Meanwhile, the rate of deforestation has a significant positive impact on CO_2 emissions in both the short and long term. This indicates that the higher the rate of deforestation, the greater the carbon emissions resulting from the reduced ability of forests to absorb carbon, as well as increased carbon releases from land-clearing activities, forest fires, and land-use changes.

Theoretically, these findings support the Environmental Kuznets Curve (EKC) for economic growth, which demonstrates a long-term relationship with emissions, as well as the Forest Carbon Theory, which emphasizes the role of forests as carbon sinksa role that diminishes with deforestation.

CONCLUSION

Based on the research findings, it can be concluded that economic growth and the rate of deforestation are related to carbon dioxide (CO_2) emissions in Indonesia, where both simultaneously contribute to explaining variations in carbon emissions, although individually they do not show a significant influence in either the short or long term. These findings indicate that increased economic activity and land-use changes have not yet become the dominant direct factors driving emissions, yet they still play a role in the overall environmental dynamics. Theoretically, the findings of this study support the concept of the Environmental Kuznets Curve and environmental economic theory, which emphasize the importance of striking a balance between economic development and environmental sustainability.

The contribution of this study lies in enriching empirical research by simultaneously integrating economic growth and deforestation variables in the Indonesian context using the Error Correction Model approach. In practical terms, these findings imply that development policies should be more focused on promoting the use of environmentally friendly energy and controlling deforestation. For future research, it is recommended to include additional variables such as energy consumption, urbanization, or environmental policies to obtain more comprehensive results.

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