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IMPACT OF ECONOMIC GROWTH AND GOVERNMENT SPENDING POLICIES ON CO2 EMISSIONS IN SOUTH SULAWESI: REGRESSION ANALYSIS AND EKC

Sunu Kun Aziz[1*], Ahmad Romadhon[2], Eko Handoyo[3]
[1-3]Ministry of Finance
E-mail: [1)] sunu.kun@kemenkeu.go.id, [2)] ahmad.romadhon@kemenkeu.go.id,
[3)] eko.handoyo@kemenkeu.go.id

Abstract

In making effective policy responses to climate change, it is necessary to understand the mechanisms that influence CO2 emissions, given that it is becoming a more urgent global issue. This research investigates how economic growth is affected by the amount of government investment in environmental initiatives, and CO2 emissions in South Sulawesi, Indonesia, using a multiple linear regression and the Environmental Kuznets Curve (EKC) approach. By analyzing secondary data from 2018 to 2022, including Gross Regional Domestic Product (GRDP) per capita, government expenditures on climate change adaptation and mitigation, and CO2 emissions, the research assesses how economic and policy actions impact environmental results. The results reveal that while economic growth significantly increases CO2 emissions, government spending on climate-related activities substantially reduces emissions. However, the EKC model does not provide evidence for the theory that there is a curvilinear relationship between economic growth and CO2 emissions in the area. The results emphasize the importance of government interventions aimed at reducing the environmental effects of economic activities and emphasize the necessity of wisely distributing public funds towards achieving sustainable development goals in South Sulawesi.

Keywords: *Economic Growth, Government Expenditure, CO2 Emissions*

1. INTRODUCTION

Understanding the mechanisms that affect CO2 emissions is essential for formulating effective policy responses as climate change becomes an increasingly pressing global issue. As cited by Priyanto (2021), Handmer et al. (2012) and the National Intelligence Council (2009) argue that the frequency and magnitude of extreme weather events, such as heatwaves and heavy rainfall in Asia, have severely impacted natural physical systems and human livelihoods. The increasing intensity of natural disasters, including floods, droughts, and typhoons, is linked to climate change in Southeast Asia. In particular, South Sulawesi, a rapidly developing region in Indonesia, is experiencing rising CO2 emissions driven by economic growth and industrial expansion. To tackle these environmental effects and advance sustainable economic growth, it is essential to grasp the complex relationship between economic actions and governmental strategies.

Government spending on environmental functions, such as climate change adaptation and mitigation, is a critical policy tool to manage these challenges. However, as Hermawan (2017) points out, allocations for environmental functions remain relatively low, comprising only a small fraction of total government expenditure. Despite their limited share, these expenditures are crucial in mitigating CO2 emissions and enhancing environmental quality. Yet, the effectiveness of such spending in reducing emissions, particularly in regions like South Sulawesi, is not well understood.

The goal of this research is to address the existing gap in knowledge by examining the correlation between economic development, the allocation of government funds to environmental initiatives, and the release of CO2 in the region of South Sulawesi. Employing a quantitative approach, we use multiple linear regression and the Environmental Kuznets Curve (EKC) model to assess whether an increase in per capita GRDP leads to higher CO2 emissions and if government spending on climate change initiatives can mitigate these emissions. By focusing on South Sulawesi, this study provides region-specific insights that are essential for informing local and national policy strategies aimed at balancing economic growth with environmental sustainability.

In particular, this study addresses three critical questions: (1) Does economic growth in South Sulawesi contribute to increased CO2 emissions? (2) What is the impact of government expenditure on climate change adaptation and mitigation on CO2 emissions in the region? (3) Does the Environmental Kuznets Curve hypothesis apply to the context of South Sulawesi, suggesting an inverted U-shaped relationship between economic growth and environmental degradation? The research seeks to offer a thorough comprehension of how economic and fiscal strategies can be enhanced to promote sustainable growth in South Sulawesi.

2. LITERATURE REVIEW

2.1. Multiple Linear Regression

In the econometric analysis of consumption functions, it is important to acknowledge that while initial models may assume a precise relationship between consumption and income, real-world data typically exhibit more variability due to additional influencing factors such as family size, member ages, and religion. Consequently, econometric models incorporate a disturbance term to account for these random variations. This adjustment leads to the modified model:

$$Y = ß_1 + ß_2 X + u$$

Where u represents the stochastic disturbance capturing the unaccounted-for influences on consumption. This formulation exemplifies a linear regression model, illustrating that while Y (consumption) is linearly related to X (income), individual deviations are acknowledged and incorporated into the analysis (Gujarati, 2003).

Based on the work of Irrawati and Mukaramah (2024), in multiple linear regression analysis, data is gathered for both the variables that are being studied and those that are being used as predictors, in order to determine the most suitable regression equation that represents the connection between these variables. The equation is used to foresee or elucidate the dependent variable's worth by relying on the established values of the independent variables. Moreover, there are several statistical methods available to evaluate the reliability of the regression model, such as examining the significance of regression coefficients, checking assumptions, and assessing the overall fit of the model. The main feature of the multiple linear regression model involves a connection where a single outcome variable (Y) is impacted by multiple predictor variables (X1, X2, ... Xn).

The key purpose of conducting multiple linear regression analysis is to estimate the outcome variable's value based on the known values of the predictor variables. The standard format of the multiple linear regression equation is represented as:

$$Y = a + b1\ X1 + b2X2 + bn\ Xn$$

In this equation, Y represents the dependent variable, a is the constant, and b_1, b_2, …, b_n are the regression coefficients. The coefficients serve as a reflection of how the dependent variable is connected to each independent variable. A positive coefficient signifies a direct correlation, whereas a negative coefficient implies an opposite relationship. On the other hand, if the coefficients are zero, it indicates that the independent variables have no impact on the dependent variable.

2.2. Environmental Kuznets Curve (EKC)

According to Stern (2014), the standard EKC regression is:

$$\ln E_{it} = \alpha_i + Y_t + \beta_1 \ln Y_{it} + \beta_2 (\ln Y_{it})^2 + \varepsilon_{it}$$

E could represent the quality of the environment surrounding or the emission levels per individual, Y stands for the per capita GDP, and ε signifies a term of random error. The parameters β_0 and β_1 represent country and time effects, respectively, at a particular income level, Y_1 and Y_2 represent the coefficients that measure the elasticity of emissions in relation to income (Stern, 2014).

3. RESEARCH METHODS

3.1. Data and data sources

The study makes use of data from various official sources that are not primary. Data were collected from *Badan Pusat Statistik* (BPS) For GRDP, population figures, and economic growth rates. Regional Government Reports To gather information on government spending and environmental policies from Ministry of Finance. Environmental Agencies For data on CO2 emissions. The study covers a period of five years (2018-2022) to ensure a comprehensive analysis of trends and changes in the relevant variables.

The data used in this thematic analysis are quantitative, comprising three variables: CO2 emissions, APBN expenditures for climate change mitigation and adaptation, and GRDP per capita. The dataset includes annual data collected from 2014 to 2022, resulting in a total of 9 observations. The data were sourced from the Signsmart platform of the Ministry of Environment and Forestry, the BPS website of South Sulawesi Province, and the Sintesa application of the Ministry of Finance. A detailed description of the variables is provided as follows:

Table 1. Description of the Variable

Code	Variable Name	Variable Description	Unit
CO_2	CO2 Emissions	CO2 Gas Emissions	Teraton CO2
$PDRB_C$	Per Capita GRDP	Gross Regional Domestic Product per capita in South Sulawesi Province	Million Rupiah
BAM	Climate Change Adaptation and Mitigation Spending	Government Spending in South Sulawesi Province for climate change adaptation and mitigation	Billion Rupiah

Source: Signsmart KLHK Website, Central Statistics Agency of South Sulawesi Province Website, Sintesa Kemenkeu Application (Processed)

3.2. Analysis Method

The key variables in this research include Gross Regional Domestic Product (GRDP) per capita, representing economic activity and development; government spending on environmental protection, indicating the extent of government intervention in environmental issues; and CO2 emissions, serving as the primary measure of environmental degradation. The study employs several analytical methods, including descriptive statistics to outline trends in economic growth, government spending, and CO2 emissions in South Sulawesi. Additionally, regression analysis is used to explore the relationships between these variables by examining the Environmental Kuznets Curve (EKC) theory, incorporating both linear and quadratic components of GDP per capita. The stages for conducting regression analysis are as follows:

1) Specification of the equation model: In this research, two approaches are employed to identify the factors influencing the increase in CO2 emissions, including:

a. Equation Model 1: Multiple linear regression model which formulated as follows.

$$\ln CO_2 = \beta_0 + \beta_1 \ln PDRB_C + \beta_2 \ln BAM + \varepsilon$$

Where:

$\ln CO_2$: The natural logarithm of the CO_2 emissions variable.
$\ln PDRB_C$: The natural logarithm of the GRDP per capita variable.
$\ln BAM$: The natural logarithm of the climate change adaptation and mitigation expenditure variable.
β_0 **:** Constant term.
β_i **:** Regression coefficient for the i-th variable, where i = 1,2.
ε **:** Error term.

b. Equation Model 2: Quadratic Environmental Kuznets Curve (EKC) model

This equation model is a quadratic model of GRDP per capita concerning CO_2 emissions, with the inclusion of climate change adaptation and mitigation expenditures. The resulting equation model is as follows:

$$\ln CO_2 = \beta_0 + \beta_1 \ln PDRB_C + \beta_2 \ln PDRB_C^2 + \beta_3 \ln BAM + \varepsilon$$

Where:
$\ln CO_2$: The natural logarithm of the CO_2 emissions variable.
$\ln PDRB_C$: The natural logarithm of the GRDP per capita variable.
$\ln PDRB_C^2$: The square of the natural logarithm of the GRDP per capita variable.
$\ln BAM$: The natural logarithm of the climate change adaptation and mitigation expenditure variable.
β_0 **:** Constant term.
β_i **:** Regression coefficient for the i-th variable, where i = 1,2.
ε **:** Error term.

2) Estimation of equation models: Equation Model 1 and Equation Model 2 are estimated using multiple linear regression with the Ordinary Least Squares (OLS) estimation method (Gujarati, 2003).
3) Classical assumption tests: The OLS estimation method requires several assumptions to be met in order for the estimator to have the properties of BLUE (Best Linear Unbiased Estimator). The assumptions that need to be satisfied are normality, no autocorrelation, and homoskedasticity (Gujarati, 2003). The classical assumption tests for normality include the Lilliefors test (Thode, 2002) and the Jarque-Bera test (Gujarati, 2003; Thadewald & Büning, 2007). The Breusch-Pagan Lagrange Multiplier (LM) test is used to evaluate the assumption of non-autocorrelation, as described by Breusch and Pagan in 1980. Meanwhile, the Breusch-Pagan-Godfrey test is utilized to assess the assumption of homoskedasticity (Breusch & Pagan, 1979).
4) Model significance assessment: The significance of the model is assessed by examining the R-squared (R^2) value. The R^2 value represents the proportion of variability in the outcome variable that can be accounted for by the predictor variables used in the model (Gujarati, 2003).
5) Parameter testing of the model: To find out how the independent variables in the model impact the dependent variable, the model undergoes parameter testing with the F-test for general significance and the t-test for specific parameter significance.

a. F Simultaneous Test

This test aims to determine whether the regression model can explain the relationship between economic growth and APBN expenditure on climate change adaptation and mitigation with CO_2 emissions in the model. This analysis aims to investigate whether there is a connection between the dependent variable and at least one independent variable. The hypotheses tested are as follows (Gujarati, 2003):

$H_0 : \beta_i = \beta_j = 0 \; ; i \neq j$
H_1: At least one $\beta_i \neq 0$; i = 1,2, … , k
With F statistics is as follows:

$$F_{hit} = \frac{R^2/k}{(1-R^2)/(t-k-1)} \sim F_{(k;t-k-1)}$$

Where:
F_{hit} : F statistics
R^2 : R squared
k : number of variables
t : number of series

The rejection of the null hypothesis done if $F_{hit} > F_{\alpha(k;t-k-1)}$. This implies that there is a significant impact of at least one independent variable on the dependent variable in the model. On the other hand, if the null hypothesis is not rejected, it means that the independent variables do not have a significant influence on the dependent variable.

b. Partial T Test

This test is conducted individually on each independent variable in the model. In this thematic analysis, the partial t-test used is a two-tailed test to determine whether there is an independent significant influence between economic growth and APBN expenditure on climate change adaptation and mitigation with CO_2 emissions. The hypotheses tested are below:

$H_0 : \beta_i = 0$, i = 1,2, … , k
$H_1 : \beta_i \neq 0$, i = 1,2, … , k

With t statistics is as follows:

$$t_{hit} = \frac{\hat{\beta}_i}{se(\hat{\beta}_i)}$$

Where:
t_{hit} : t statistics
$\hat{\beta}_i$: parameter estimator for i-th variable
$se(\hat{\beta}_i)$: standard error of parameter estimator for i-th variable

The rejection of the null hypothesis done if $t_{hit} > \left|t_{\frac{\alpha}{2}(k-1)}\right|$. This implies that the independent variable has a strong impact on the dependent variable. On the other hand, if the null hypothesis is not accepted, then the independent variable does not have a significant effect on the dependent variable.

6) Determination of the turning point of the quadratic effect of the Environmental Kuznets Curve. According to the Environmental Kuznets Curve (EKC) theory, when per capita income rises initially, CO2 emissions also increase. However, once a specific level of per capita income is reached, further increases in income will result in a decrease in CO2 emissions due to the adoption of eco-friendly technologies. To determine this income turning point, calculations are carried out using a specific formula derived from the estimation results.

$$TP = -\frac{\hat{\beta}_{linear}}{2\hat{\beta}_{quadratic}}$$

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Where:
TP : Turning point
$\hat{\beta}_{linear}$: The estimate of the parameter for the linear effect
$\hat{\beta}_{quadratic}$: The estimate of the parameter for the quadratic effect

4. RESULTS AND DISCUSSION

4.1. Government Interventions through Expenditure Policies

Table 2. Budget and Realization of the State Budget (APBN for Climate Change (2021-2023) in Billion Rupiah

Department/Agency Description	2021		2022		2023	
	Budget	Realization	Budget	Realization	Budget	Realization
Ministry of Environment and Forestry	28.75	28.70	86.44	80.34	62.80	56.68
Ministry of Transportation	33.64	33.61	28.17	28.04	21.12	21.01
Ministry of Agriculture	10.29	8.99	4.42	4.40	0.08	0.07
Public Broadcasting Institution Radio Republic of Indonesia	2.30	2.26	1.99	1.95	0.05	0.04
Meteorological, Climatological, and Geophysical Agency	7.30	7.14	1.79	1.79	0.88	0.88
Climate Change Budget (a)	82.28	80.70	122.82	116.52	84.92	78.68
Total State Budget (APBN) for Ministries/Agencies in South Sulawesi (b)	2,729.51	2,659.33	2,844.22	2,776.58	3,136.53	3,036.76
Percentage of Climate Change Budget to Total State Budget of South Sulawesi (a/b)	3.01%	3.03%	4.32%	4.20%	2.71%	2.59%

Source: Processed from the Ministry of Finance Sintesa Application

Over the last three years, the budget for climate change initiatives in South Sulawesi's national budget has been distributed among five different ministries and agencies, with varying amounts. The amount allocated to climate change in the budget for these ministries/agencies is relatively small, usually between 2 to 4 percent each year compared to the total APBN. The highest share was recorded in 2022, reaching 4.3 percent. The climate change funding is separated into two key sectors: addressing climate change and adapting to climate change.

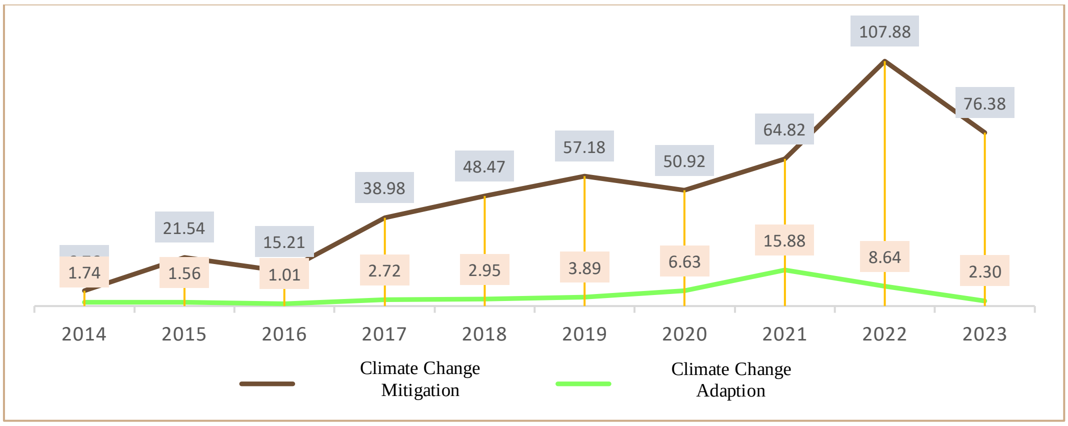

Figure 1. Development of Climate Change Mitigation and Adaptation Realization (in billion rupiah)

Source: Processed from the Ministry of Finance Sintesa Application

The budget realization for climate change mitigation has consistently exceeded that for climate change adaptation over the past decade. While the realization of the climate change mitigation budget has fluctuated, it has generally shown an upward trend until 2022, followed by a decline in 2023. The highest realization in 2022 was driven by the Forest Rehabilitation program, which accounted for Rp45.79 billion. Similarly, the realization of the climate change adaptation budget has also fluctuated, with the highest realization occurring in 2021 due to the Plant Protection Management program, amounting to Rp8.53 billion

4.2. Analysis of the Impact of Per Capita Gross Regional Domestic Product (GRDP) and Government Spending on Climate Change on CO2 Emissions (Greenhouse Gas Emissions)

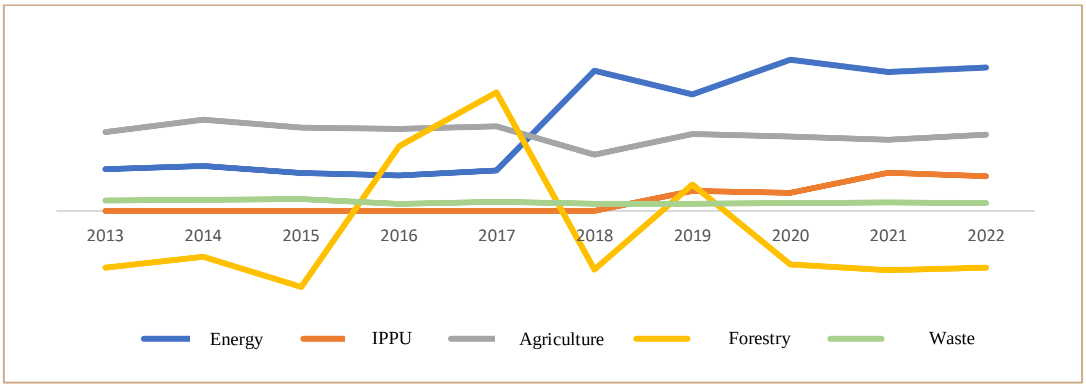

Figure 2. Development of Greenhouse Gas Emissions in South Sulawesi

Source: Central Statistics Agency of South Sulawesi Province (South Sulawesi in Figures) - Processed

From 2018 to 2022, greenhouse gas (GHG) emissions were predominantly driven by the energy sector. In contrast, from 2013 to 2017, the highest GHG emissions were primarily influenced by the agricultural sector. This shift indicates a transition in the population's activities from agriculture to the energy sector. In South Sulawesi, energy sector emissions stem from transportation, manufacturing & construction, and the energy industry. The highest emissions occurred in 2022, reaching 43.32 Gg of CO2, with energy sector emissions accounting for 23.68 Gg of CO2, which is more than 50 percent of the total emissions.

4.2.1. Regression Analysis

1) Identification of the Equation Model and Model Estimation

The equation model to be estimated involves CO2 emissions as the dependent variable, while GRDP per capita and climate change adaptation and mitigation expenditures serve as the independent variables. For the CO2 emissions analysis, two equation models are employed:

2) Testing of Classical Assumptions

Classical assumptions are tested after estimating both Equation Model 1 and Equation Model 2. After conducting tests on classical assumptions, it has been determined that all of these assumptions have been satisfied. Therefore, the estimation of the multiple linear regression model produces a BLUE (Best Linear Unbiased Estimator) estimator.

Table 3. Results of Assumption Testing for "Impact of Per Capita Gross Regional Domestic Product (GRDP)" using e-Views

Model Equation 1: Multiple Linear Regression Model				
Assumption	**Test**	**Test Statistic**	**p-value**	**Decision**
Normality	Lilliefors Test	0.2722	0.1054	Normal
Homoscedasticity	Breusch-Pagan-Godfrey Test	0.3345	0.7283	Homoscedasticity
Non-Autocorrelation	Breusch-Godfrey LM Test	0.2406	0.7968	Non-Autocorrelation
Model Equation 2: Quadratic EKC Model				
Assumption	Test	Test Statistic	p-value	Decision
Normality	Jarque-Bera Test	12.448	0.5366	Normal
Homoscedasticity	Breusch-Pagan-Godfrey Test	16.247	0.296	Homoscedasticity
Non-Autocorrelation	Breusch-Godfrey LM Test	0.6618	0.578	Non-Autocorrelation

Source: Compiled by the authors

3) Regression Estimation

The equation model estimation was conducted using the E-Views application, with the following regression estimation results:

Table 4. Regression Results using e-Views

Independent Variable	Dependent Variable: ln CO_2	
	Equation 1	**Equation 2**
Constant	-26.076**	-135.2088
	(-2.8041)	(-1.0950)
$\ln PDRB_C$	9.3254**	71.9325
	(3.0336)	(1.0175)
$\ln PDRB_C^2$		-8.9743
		(-0.8864)
$\ln BAM$	-0.9578*	-0.9393*
	(-2.1743)	(-2.0915)
R^2	0.7278	0.7648
$Adj\ R^2$	0.6371	0.6237
F_{stat}	8.0220**	5.4190**
p-value	0.0202	0.0498

Note: Values in parentheses are t-statistics. Significance levels are indicated as follows: 5 percent significance level and *10 percent significance level.

4) Equation 1: Multiple Linear Regression Model

$$\ln \widehat{CO}_2 = 26{,}076 + 9{,}3254 \ln PDRB_c - 0{,}9578 \ln BAM$$

a. Coefficient of Determination (R^2)

As shown in Table 4, the R^2 value is 0.7278, signifying that the independent variables in the model account for 72.78% of the fluctuation in CO_2 emissions. The remaining 27.22% of the variation is attributed to variables not accounted for in the model.

b. Simultaneous F-Test

Table 4 shows the regression results, revealing that the value of F_{hit} is 8.0220 and the p-value is 0.0202. With a significance level of 5%, the simultaneous F-test suggests a notable outcome, suggesting that there is a significant impact from at least one independent variable on the rise in CO_2 emissions.

c. Partial t-Test:

Based on Table 4, the partial t-test results are as follows:

- Economic Growth Coefficient $(\widehat{\beta_1} = 9{,}3254)$

The economic growth variable has a t-statistic coefficient value of 3.0336, which is significant at the 5% significance level. This indicates that economic growth significantly influences the increase in CO_2 emissions. The coefficient value of this variable, 9.3254, indicates that every 1% increase in economic growth will increase CO_2 emissions by 9.3254%, assuming other variables remain constant (ceteris paribus).

- APBN Expenditure for Climate Change Adaptation and Mitigation Coefficient $(\widehat{\beta_2} = -0{,}9578)$

The APBN expenditure variable for climate change adaptation and mitigation has a t-statistic coefficient value of -2.1743, which is significant at the 5% significance level. This indicates that the APBN expenditure on climate change significantly influences the

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reduction of CO_2 emissions. The coefficient value of this variable, -0.9578, shows that every 1% increase in APBN expenditure on climate change will reduce CO_2 emissions by 0.9578%, assuming other variables remain constant (ceteris paribus).

5) Equation 2: Quadratic EKC Model

$$\ln \widehat{CO}_2 = -135{,}2088 + 719325 \ln PDRB_c - 8{,}9743 \ln PDRB_c{}^2 - 0{,}9393 \ln BAM$$

Interpretation:

a. Coefficient of Determination (R^2)

According to the data presented in Table 4, the R^2 value is 0.7648, suggesting that 76.48% of the changes in CO_2 emissions can be attributed to the independent variables used in the model. The remaining 23.52% of the changes are influenced by factors not considered in the model.

b. Simultaneous F-Test:

According to the data in Table 4, the F_{hit} value is 5.4190 and the p-value is 0.0498. The significance level of 5% is exceeded, meaning the simultaneous F-test demonstrates a significant outcome, suggesting that at least one independent variable plays a significant role in increasing CO_2 emissions.

c. Partial t-Test:

According to the information presented in Table 4, the results of the partial t-test can be summarized as follows:

- Economic Growth Coefficient$\left(\widehat{\beta_1} = 71{,}9325 \text{ and } \widehat{\beta_2} = -8{,}9743\right)$

The economic growth variable, along with its quadratic effect, was found to be insignificant in the estimation results of this equation model. Therefore, one can conclude that the theory of the Environmental Kuznets Curve does not hold true for the Sulawesi area, indicating that there is not a correlation between economic development and the release of CO_2.

- APBN Expenditure for Climate Change Adaptation and Mitigation Coefficient $\left(\widehat{\beta_3} = -0{,}9393\right)$

The APBN expenditure variable for climate change adaptation and mitigation has a t-statistic coefficient value of -2.0915, which is significant at the 5% significance level. This indicates that the APBN expenditure on climate change significantly influences the reduction of CO_2 emissions. The coefficient value of this variable, -0.9393, shows that every 1% increase in APBN expenditure on climate change will reduce CO_2 emissions by 0.9393%, assuming other variables remain constant (ceteris paribus).

5. CONCLUSION

This research examines how economic growth and government expenditure affect measures taken to adapt to and mitigate climate change and reduce CO_2 emissions in South Sulawesi. It will use multiple linear regression and the Environmental Kuznets Curve (EKC) approach for analysis. The findings reveal that economic growth, as measured by GRDP per capita, significantly increases CO_2 emissions in the region, suggesting that the current trajectory of economic development is closely linked to higher levels of environmental degradation. Conversely, government spending on climate-related activities is found to significantly reduce CO_2 emissions, indicating that targeted public expenditure plays a crucial role in mitigating the adverse environmental impacts of economic activities.

The analysis conducted does not provide evidence for the Environmental Kuznets Curve theory, which suggests a non-linear correlation between economic growth and CO_2 emissions in South Sulawesi. This suggests that in the current context, economic growth does not yet lead to environmental improvements, even as income levels rise. Instead, the positive correlation between growth and emissions indicates that the region's economic activities remain dependent on carbon-intensive practices.

These findings underscore the need for a strategic shift in public policy to balance economic growth with environmental sustainability. Given the significant role of government spending in reducing emissions, policymakers should consider increasing allocations for climate change adaptation and mitigation, particularly in sectors such as renewable energy, sustainable agriculture, and green infrastructure. Additionally, the lack of evidence supporting the EKC model in South Sulawesi suggests that economic growth alone is insufficient to achieve environmental sustainability; proactive government interventions and investments in low-carbon technologies are essential.

Future studies should investigate how various forms of government expenditure impact carbon dioxide emissions, such as investments in renewable energy and energy efficiency, to better understand which strategies are most effective in reducing emissions. Furthermore, by including a wider array of ecological measures and taking into account extended timeframes, a more thorough understanding of the complex interplay between economic development and environmental well-being in South Sulawesi could be achieved.

This research sheds light on the intricate connection between economic advancement, governmental strategies, and ecological consequences. It adds depth to our comprehension of how policies can be fine-tuned to promote sustainable progress in South Sulawesi and other areas dealing with the competing interests of economic growth and environmental protection.

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