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ANALYSIS OF DETERMINANTS OF CO2 EMISSIONS IN THE ENERGY SECTOR AS A REFLECTION OF THE GREEN ECONOMY IN INDONESIA, 2000 - 2022

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ABSTRACT

Global CO2 emissions are increasing, especially in developing countries such as Indonesia, which is the highest contributor to carbon emissions in ASEAN. This research analyzes the factors that influence CO2 emissions in the Indonesian energy sector from 2000 to 2022. Data from BPS, World Energy, the World Bank, and the Ministry of Energy and Mineral Resources (ESDM) were used to analyze the relationship between CO2 emissions and variables such as GDP, Foreign Direct Investment (FDI), population density, and final energy consumption using multiple linear regression analysis. The findings show that GDP and Final Energy Consumption have a significant relationship with increasing CO2 emissions, while FDI and population density are not statistically significant. However, these two factors still need to be considered in designing future emission reduction policies. The policy recommendations include the adoption of renewable energy, improvements in energy efficiency, and the need for further research to gain a comprehensive understanding of the factors influencing CO2 emissions across different sectors.

Emisi CO2 global meningkat, terutama di negara-negara berkembang seperti Indonesia, yang merupakan penyumbang tertinggi emisi karbon di ASEAN. Penelitian ini menganalisis faktor-faktor yang memengaruhi emisi CO2 di sektor energi Indonesia dari tahun 2000 hingga 2022. Data dari BPS, World Energy, World Bank, dan Kementerian ESDM digunakan untuk menganalisis hubungan antara emisi CO2 dengan variabel seperti PDB, *Foreign Direct Investment*, Kepadatan Penduduk, dan Konsumsi Energi Final menggunakan analisis regresi linier berganda. Temuan menunjukkan bahwa PDB dan Konsumsi Energi Final memiliki hubungan signifikan dengan peningkatan emisi CO2, sementara FDI dan kepadatan penduduk tidak signifikan secara statistik. Namun demikian, kedua faktor tersebut tetap perlu dipertimbangkan dalam merancang kebijakan pengurangan emisi di masa depan. Rekomendasi kebijakan yang ditawarkan mencakup pemanfaatan energi terbarukan, peningkatan efisiensi energi, dan perlunya melakukan penelitian lebih lanjut untuk memahami secara menyeluruh faktor-faktor yang memengaruhi emisi CO2 di setiap sektor.

1. INTRODUCTION

1.1.Backgrounds

Climate change is a critical issue that has received global attention because of its detrimental impacts, especially on the economy and the environment. The increase in carbon emissions, which is one of the main causes of climate change, is largely caused by human activities, especially with the ongoing population growth (Ferdiansyah et al, 2023). An increase in human population leads to increased economic activity, which in turn increases the use of natural resources and produces carbon emissions. The impact of global warming has become increasingly apparent with the significant rise in Earth's temperature over the last 14 decades. Additionally, global warming is also increasing Earth's CO2 emissions, as supported by data from various world institutions such as NASA and NOAA in Figure 1.

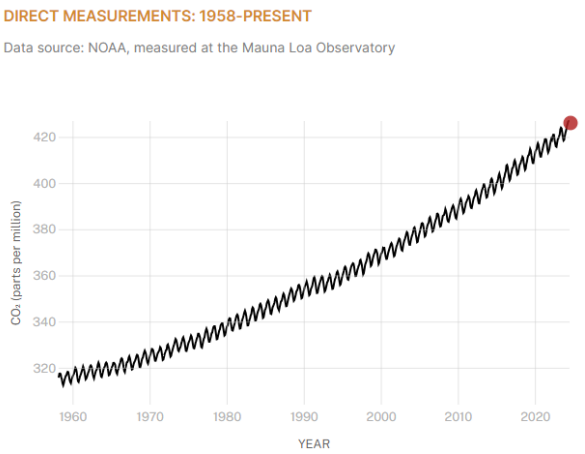

Figure 1: Global CO2 Emissions Trends, 1958 - Present
Source: NASA (2024)

Greenhouse gas emissions, especially CO2, have increased significantly with the energy sector being one of the largest contributors in Indonesia. Even though the Indonesian government has succeeded in controlling emissions from the Forest and Other Land Use (FOLU) sector (Coordinating Ministry for Economic Affairs RI, 2021), emissions from the energy sector remain the largest until 2020. Therefore, further analysis is needed to understand the factors that influence CO2 emissions from the energy sector in Indonesia, and its impact on efforts to achieve a Green Economy.

The green economy is a long-term strategy to address crises and recover the national economy, focusing on providing inclusive job opportunities (Setiyowati et al, 2023). The green economy is divided into three pillars: economic, social, and environmental (Ferdiansyah et al, 2023). This study analyzes economic growth and foreign investment for the economic pillar to assess alignment with green economy principles. The social pillar is represented by Indonesia's population growth, proxied by population density, which affects economic and environmental activities. The environmental pillar is represented by the percentage of renewable energy to total energy in Indonesia.

According to Ferdiansyah et al (2023), *Foreign Direct Investment* (FDI) has a significant influence on CO2 gas emissions in Indonesia. This finding is in line with research by Winda & Falianty (2023), which states that FDI has a significant effect on CO2 emissions in G20 member countries. However, research by Ferdiansyah et al (2023) also found that FDI has a negative influence on CO2 gas emissions in Indonesia. In Indonesia, foreign investment in the agriculture sector can reduce emissions because this sector is more environmentally friendly (Ferdiansyah et al, 2023).

Apart from FDI, Gross Domestic Product (GDP) also has a significant influence on CO2 emissions, as found in research by Hao et al (2021) in G7 member countries and by Raza et al (2023) in Bangladesh. Zuhri (2014) found that population density had a positive and significant effect in increasing CO2 gas emissions in Indonesia, although research by Puspitasari (2023) shows that population density has a negative and significant influence in reducing the quality of the environment in Indonesia. In addition, research by Kurniarahma et al (2020) shows that energy consumption has a significant influence on CO2 emissions in Indonesia in the short term, although it has no effect in the long term, in line with research by Madyan et al (2022) who found that energy consumption has a significant and negative influence in reducing CO2 emissions in Indonesia.

By considering these studies, this research will further analyze the factors that influence CO2 emissions from the energy sector in Indonesia, as well as the impact of these factors on the three pillars that make up the Green Economy.

2. THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

2.1. Energy Sector CO2 Gas Emissions

Greenhouse gas emissions (GHG) are the release of gases such as Carbon dioxide (CO2), Methane (CH4), Nitrogen (N2O), and Chloro Fluoro Carbon (CFC) into the atmosphere over a certain period. In the Indonesian context, the energy sector and the Forest and Other Land Use (FOLU) sector are the largest contributors to CO2 emissions. Even though emissions from the FOLU sector have been successfully reduced (Coordinating Ministry for Economic Affairs RI Kemenko Perekonomian RI, 2021), the energy sector is still a problem that needs to be addressed immediately. CO2 emissions from the energy sector can come from various sources, such as the burning of fossil fuels, power plants, industry, transportation and households (Purwanta, 2016). Therefore, this research will focus on CO2 gas emissions from the energy sector in Indonesia.

2.2. Gross Domestic Product at Constant Prices (ADHK GDP)

Gross Domestic Product (GDP) is the added value of all business units in a country in a certain time

period. There are two types of GDP, namely GDP at current prices (Nominal GDP) and GDP at constant prices (Real GDP). Nominal GDP describes the added value of goods and services in the current year using the prices of goods and services in effect in that year, while Real GDP describes the added value using the prices of goods and services in a predetermined base year. Nominal GDP is used to analyze economic structure, while Real GDP is used to see a country's economic growth from year to year. This research uses GDP at constant prices to identify whether economic growth influences the increase of CO2 gas emissions. According to Ferdiansyah et al (2023), economic growth significantly contributes to carbon emissions because the expansion of industries, especially in manufacturing, increases air pollution and carbon emissions. Higher production and consumption lead to greater productivity, which often involves more machinery, resulting in increased carbon emissions.

2.3. *Foreign Direct Investment*

Foreign Direct Investment (FDI) is an international capital flow used by a company that owns or expands its business in another country. The influx of FDI will affect a country's national productivity rate due to multiplier effects such as the transfer of capital, technology, managerial skills and knowledge from other countries that invested to that country (Radifan & Saputra, 2022). However, if investments shift to the industrial sector, carbon emissions might increase. Therefore, the impact of FDI on CO2 emissions depends on the sector receiving the investment.

According to Pazienza (2015) foreign investment affects carbon emissions in different ways. In Indonesia, while industrial and transportation sectors receive a lot of foreign investment, the agriculture sector also gets significant investment. Investments in agriculture can reduce carbon emissions because this sector is generally more environmentally friendly than industry. However, if foreign investments move to non-agricultural sectors like industry, carbon emissions might increase. So, FDI can both lower and raise CO2 emissions depending on which sector it targets.

2.4. Population density

The concept of population refers to the people who live in a place, be it a region or a country, and is often considered an asset in the development or human resources (HR) of a region. Population density is the ratio between the number of people in an area and the area of that area, calculated using the formula. Over time, the population tends to increase while the area remains constant, which can cause environmental problems such as the availability of clean water, poor sanitation, and air pollution. Increasing population density in an area contributes to a rise in environmental problems, especially air pollution, which in turn leads to higher emissions of greenhouse gases and other pollutants (Yani et al, 2023).

2.5. Final Energy Consumption

Energy is the ability of a system to do a work on another system (Aris Raharjo & Riadi, 2013). Energy consumption is the amount of energy used in a certain time period (Suyono & Prianto, 2018). Meanwhile, the definition of final energy consumption according to Eurostat Statistics Explained is the energy that can be directly consumed by end users. The end users that referred to here includes households, industry, and agriculture. A study by Hashimoto (2019) found that because increased primary energy consumption directly contributes to higher concentrations of CO2 emissions in the atmosphere, the only solution to prevent this is to use renewable energy without fossil fuel combustion.

3.RESEARCH METHODS

The analytical method used to achieve the research objectives is descriptive analysis and multiple linear regression analysis. Descriptive analysis is used to answer the first objective. Meanwhile, multiple linear regression analysis was used to answer the second and third research objectives.

Descriptive Analysis

Augmented Dicky-Fuller (ADF) Test

This test was carried out to find out whether the Yt model can be defined as a random walk. The procedure for determining data stationarity is to compare the ADF statistical value with the critical value. If in testing the ADF at the level obtaining a decision that the data is not stationary then a data differentiation process must be carried out.

Hypothesis

H_0: $\delta = 0$or (Data is not stationary)$\rho = 1$

H_1: $\delta \neq 0$or (Stationary data)$\rho \neq 1$

Test Statistics

$$r = \frac{\hat{\rho}}{se(\hat{\rho})}$$

The criteria in the ADF test are if the p-value <0.05, then the decision is to reject H0. This proves that the data is stationary.

Inferential Analysis

Multiple Linear Regression

Linear regression analysis is an analysis carried out to determine the linear relationship between the dependent variable and one or more independent variables. This research uses a multiple linear regression analysis method because there is more than one independent variable to be analyzed. The method used to estimate the parameters of the multiple linear regression model in this research is the ordinary least squares (OLS) method. The OLS method can be used only when the parameters are linear or to the power of one. Multiple linear regression analysis also requires linear data in its application. For this reason, it is necessary to check the linearity of the data using a scatter plot before multiple linear regression analysis. Once the data is confirmed to be linear, it can be continued with multiple linear regression analysis. The

resulting regression model looks like this:

$Y_t = \beta^0 + \beta_1 PDB_t + \beta_2 FDI_t + \beta_3 DEN_t + \beta_4 KEF_t + \varepsilon_t$

Information:

Y_t: Dependent variable,

β_0: Constant,

$\beta_{1\ldots4}$: Partial regression coefficient on the independent variable,

PDB_t: t-th Gross Domestic Product,

FDI_t: t-th *Foreign Direct Investment*,

DEN_t: t-th Population Density,

KEF_t: t-th Final Energy Consumption,

ε_t: Error termIn

Simultaneous Test

Simultaneous testing using the F test is carried out to prove whether the independent variables together have a significant influence on the dependent variable.

Hypothesis

$H_0: \beta_1 = \beta_2 = 0$(the model cannot explain the relationship between variables)

$H_1: minimum\ of\ one\ \beta_j \neq 0, j = 1,2$(the model can explain the relationship between variables)

Test Statistics

$$F_{hitung} = \frac{MSR}{MSE}$$

The criterion in the t test is if the p-value <0.05, then the decision is to reject H0. This means that the model can explain the relationship between variables or in other words there is at least one independent variable that significantly influences CO2 gas emissions.

Partial Test

Individual parameter significance tests are carried out to determine whether the independent variable partially has a significant influence on the dependent variable.

Hypothesis

$H_0: \beta_i = 0$ (there is no influence of the independent variable on the dependent variable)

$H_1: \beta_j \neq 0$ (there is no influence of the independent variable on the dependent variable)

Test Statistics

$$t_{count} = \frac{b_1}{se(b_1)}$$

Information:

b_1 : regression coefficient

$se(b_1)$: standard error of the regression coefficient

If the calculated t is greater than the t table, then it can be concluded that there is sufficient evidence that the independent variable has a partially significant effect on the dependent variable.

Classic assumption test

In calculating regression parameter estimates, the ordinary least squares (OLS) method is used to produce regression coefficients. The model will be blue (best linear unbiased estimator) if it meets several assumptions. In this study, tests of the assumptions of homoscedasticity, non-multicollinearity, and normality were carried out. The classic assumption test of homoscedasticity aims to test whether the variance values between the residuals in the regression model are the same. In multiple linear regression analysis, it is expected that the residual values have the same or similar variance. In this study, the Breusch-Pagan test was used to determine whether homoscedasticity occurred or not. Here is the hypothesis.

$H_0: var(\varepsilon_i) = \sigma^2$ or constant residual value (homoscedastic)

$H_1 : var(\varepsilon_i) = \sigma^2$ or the residual value is not constant (heteroscedastic)

The Breusch-Pagan test statistic follows a chi-square distribution. If the calculated chi-square value is smaller than the chi-square table, then there is no heteroscedasticity or the homoscedasticity assumption is met. The p-value can also be used, if the p-value is greater than the significance level, then the assumption of homoscedasticity is also met.

The final test, namely the normality test, aims to find out whether the residuals from the data are normally distributed or not. In this study, the Lilliefors statistical test was used in the normality test. Here is the hypothesis.

$H_0: X \sim N(\mu, \sigma^2)$or normally distributed data

$H_1: X \nsim N(\mu, \sigma^2)$ or the data is not normally distributed.

In this case, it is hoped that H0 will fail so that the data is normally distributed. Data normality is needed as a condition for knowing the Pearson correlation coefficient or the Pearson correlation test between variables. When the data is not normally distributed, data transformation is carried out.

This research uses annual time series data for the period 2000 to 2022, with a total of 23 observations. The variables used are CO2 gas emissions (CO2), Gross Domestic Product (GDP) at constant prices, *Foreign Direct Investment* (FDI), population density (DEN), and final energy consumption (FEC).

The data used is secondary data in the form of time series data. Details of the data sources for each variable are as follows: CO2 (CO2) gas emissions data were obtained from the 2023 Statistical Review of World Energy, Gross Domestic Product (GDP) data on the basis of constant prices and population density (DEN) were obtained from the Indonesian Central Bureau of Statistics (BPS), *Foreign Direct Investment* (FDI) data obtained from the World Bank, and final energy consumption (FEC) data obtained from publications from the Ministry of Energy and Mineral Resources (ESDM).

Table1. Variable Name, Description, and Unit

No.	Variable Name	Description	Units
1	CO2	CO2 gas emissions	Million tons
2	GDP	ADHK Gross Domestic Product	Trillions of Rupiah
3	FDI	*Foreign Direct Investment*	Percent
4	DEN	Population density	Persons/ km2

5	FEC	final energy consumption	*Barrels of Oil Equivalent (BOE)*

4. RESEARCH RESULTS

Descriptive Analysis

Based on Figure 1, CO2 emissions in the energy sector continued to increase from 2000 to 2019. However, they decreased from 562.70 (thousand tons) in 2019 to 512.90 (thousand tons) in 2020. This happened because of the The Covid-19 pandemic has hampered most production activities, including in the energy sector. In 2021 CO2 emissions began to increase again and will move significantly until 2022. In aggregate, CO2 emissions in the energy sector have experienced growth of 162% or almost doubled from 2000 to 2022.

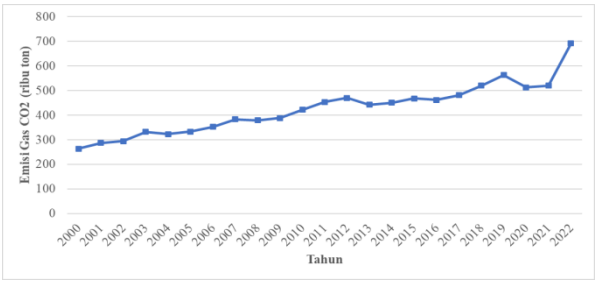

Figure 2: Development of CO2 Gas Emissions in the Energy Sector in Indonesia 2000-2022
Source: Statistical Review of World Energy, 2023

The Gross Domestic Product based on constant price value uses the base year 2010. The Gross Domestic Product based on constant price value continues to increase during the 2000 - 2019 period (Figure 2). The increase also tends to be linear, which means that the constant price gross domestic product value grows steadily and gradually and does not fluctuate. This illustrates that Indonesia's productivity, both goods and services, continues to increase in quantity.

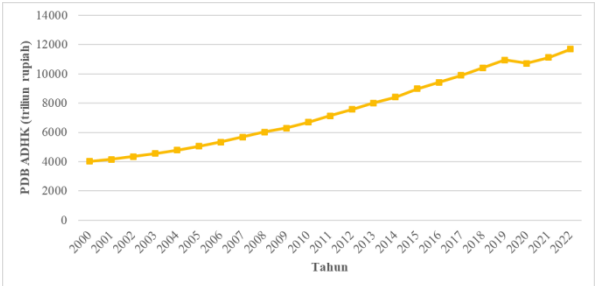

Figure 3: Development of ADHK Gross Domestic Product (GDP) in Indonesia 2000-2022
Source: Central Bureau of Statistics (BPS)

The FDI value generally tends to increase, but in 2016 it experienced a very significant decline, namely -77.03% compared to the previous year. This is the impact of the slowing global economy and economic uncertainty which has reduced foreign investment into developing countries. However, the value of FDI strengthened again until 2019 and then tended to decline again until 2022. Apart from that, it can also be seen from Figure 3 that there were negative FDI values in certain years, namely 2000, 2001 and 2003. Value of *Foreign Direct Investment* (Negative FDI), meaning that the amount of *Foreign Direct Investment* attracted is greater than what comes in, can be caused by several factors such as unattractive economic conditions, the global financial crisis, changes in government policy, and various other factors.

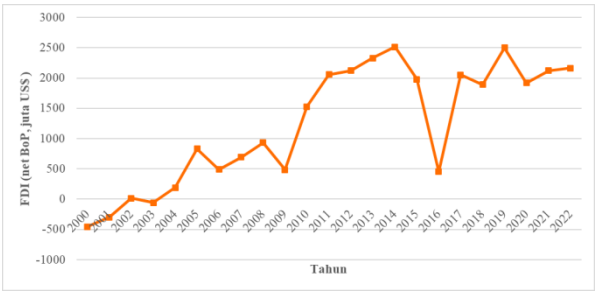

Figure 4: Development of FDI in Indonesia 2000-2022
Source: World Bank

Indonesia's population density figures tend to experience a positive trend from 2000 to 2022. However, in 2002 there was a decrease in population density from 114 to 112 compared to the previous year. This indicates that there is a higher level of mortality or out-migration than fertility or in-migration. In 2022 the population density will reach 145/km2, which means that every 1 km2 of Indonesian territory will have 145 residents.

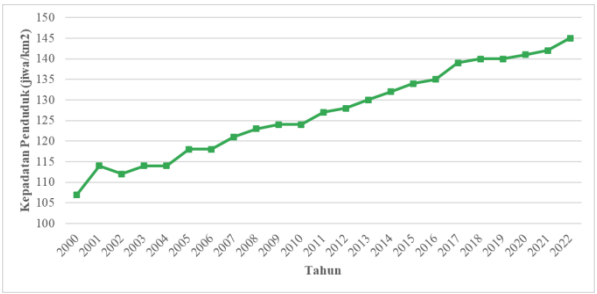

Figure 5: Development of population density in Indonesia 2000-2022
Source: Central Bureau of Statistics (BPS)

Indonesia's final energy consumption relatively increased from 2000 to 2011. However, in 2012 there was a very significant decline, namely from 1114.7 million barrels to 917.69 million barrels or the equivalent of 17.67%. This decline continued until 2016 and then increased again until 2022.

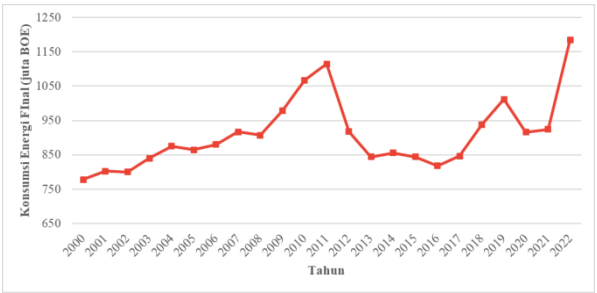

Figure 6: Development of final energy consumers (million barrels) in Indonesia 2000-2022
Source: Directorate General of Mineral and Coal Republic of Indonesia

Inferential Analysis

Stationarity Test

The results of ADF testing at level resulted in the decision that all variables in this study were not stationary at level. Therefore, it is necessary to carry out a data differentiation process so that all variables are stationary.

Table 2. Stationarity Test Results at Level

Variables	p-value	Decision
CO2	0.9733	Fail to Reject H_0
GDP	0.9989	Fail to Reject H_0
FDI	0.3173	Fail to Reject H_0
DEN	0.9709	Fail to Reject H_0
FEC	0.5778	Fail to Reject H_0

Source: processed data

Based on the ADF test results in the first differentiation, all variables produce a reject decision. Therefore, with a significance level of 5% there is sufficient evidence that all variables are stationary in the first differentiation. Variables that have been differentiated first can be used for multiple linear regression analysis.

Table 3. Stationarity Test Results in First Differentiation

Variables	p-value	Decision
DCO2	0.0001	Reject H_0
DPDB	0.0126	Reject H_0
DFDI	0.0000	Reject H_0
DDEN	0.0000	Reject H_0
DFEC	0.0090	Reject H_0

Source: processed data

Regression Model Parameter Estimation

The estimation of regression coefficient parameters in this study uses the Ordinary Least Square (OLS) estimation method resulting in the following equation.

$$\hat{DCO2}_{t-1} = -14{,}7841 + 0{,}6889 DPDB^{*}_{t-1} * -0{,}0022 DFDI_{t-1} + 2{,}5774 DDEN_{t-1} + 0{,}3228 DKEF^{*}_{t-1} \quad (1)$$

Note: * = sig. 5%

Table 4. F-test value, P-value, and Adj R-squared

Statistics	Mark
F-test	9.8880
p-value	0.0002
Adj R-squared	0.6994

Source: processed data

In the Table 4, the adjusted R square value is 0.6994. This means that 69.94% of the variation in CO2 gas emissions can be explained by the variation in the variables Gross Domestic Product at constant price, FDI, population density and final energy consumption. Meanwhile, 30.06% of the variation in CO2 gas emissions is explained by other variables.

Table 5. Multiple Linear Regression Estimation Results

Variables	Coefficient	p-value	Decision
DPDB	0.6889	0.0493	Reject H_0
DFDI	-0.0022	0.8085	Fail to Reject H_0
DDEN	2.5774	0.3996	Fail to Reject H_0
DFEC	0.3228	0.0002	Reject H_0

Source: processed data

Based on the results of the simultaneous test on Table 5, with a significance level of 5% and in this sample it can be proven that there is at least one independent variable that influences CO2 gas emissions so that the model can explain the relationship between variables. Meanwhile, the partial test on the Student-T statistical value is a significance test for individual parameters. The statistical value shows how far the influence of the independent variable individually has on the dependent variable.

Based on the results of the partial test calculated using R Studio software on Table 5, it resulted in a decision to fail to reject the FDI and population density variables. Therefore, with a confidence level of 95% and with the available samples it can be shown that the variables FDI and population density each do not have a significant influence on CO2 gas emissions. Meanwhile, the decision to reject is found in the variables Gross Domestic Product at constant price and final energy consumption. Based on this, with a significance level of 5% and with the available samples it can be shown that the Gross Regional Domestic Product at constant price variable and final energy consumption have a significant influence on CO2 gas emissions.

Classic assumption test

Based on the existing regression equation, a classical assumption test can be carried out to find out whether the equation formed is valid. Valid regression equations can be generalized to explain the phenomena that occur. These assumption tests include non-linearity assumptions, homoscedasticity assumptions, normality assumptions, and autocorrelation assumptions.

Table 6. Classic Assumption Test Results

Classical Assumptions	Test Statistics	p-value	Decision
Normality	0.1681	0.1088	Failed to RejectH_0
Homoscedasticity	2.8599	0.5815	Failed to RejectH_0
Non-Autocorrelation	1,895	0.3962	Failed to RejectH_0

Source: processed data

The first classic assumption is the normality assumption. The normality test was carried out using the Lilliefors test and failed to reject decision with p-value = 0.1088. Therefore, with a confidence level of 95% and with the available samples it can be shown that the regression model formed has errors that are normally distributed so that they meet the normality assumption.

The second classic assumption is the homoscedasticity assumption. Using the Breusch-Pagan test produces a decision to fail to reject with p-value = 0.5815. Therefore, with a confidence level of 95% and with the available sample it can be shown that the regression model formed has the same variance between populations or is homoscedastic so that it meets the assumption of homoscedasticity.

The third classic assumption is the non-autocorrelation assumption. Using the Durbin-Watson test produces a decision to fail to reject with p-value = 0.3962. Therefore, with a confidence level of 95% and with the available sample it can be shown that the regression model formed meets the non-autocorrelation assumption. Thus, all independent variables in the model meet the assumptions to form the best regression model.

Gross Domestic Product (GDP) has a significant relationship with increasing CO2 gas emissions (see Table 4). This is also in accordance with the GDP graph (see Figure 2) which continues to increase every year and is followed by the CO2 gas emissions graph (see Figure 1) which also tends to continue to increase. In 2020 there was a decline in GDP values which was followed by a decline in CO2 gas emissions. This finding is in accordance with research by Raza et al. (2023) which states that GDP plays a significant role in increasing CO2 emissions in several other countries. In the regression equation above, every change in GDP that increases during one year by one trillion rupiah will increase CO2 gas emissions by 0.6889 million tons assuming other variables are constant.

Foreign Direct Investment (FDI) does not have a significant relationship with CO2 emissions (see Table 4). This finding contrasts with the research by Ferdiansyah et al. (2023), which stated that FDI significantly affects CO2 emissions. According to their study, FDI plays a role in boosting industrialization processes. High industrial productivity leads to increased CO2 emissions in the IPPU (industrial process and production use) sector. However, this study uses CO2 emission data from the energy sector only. As a result, while the relationship between FDI and CO2 emissions in this study is also negative, it is not significant.

Population density has an insignificant relationship with CO2 gas emissions (see Table 4). This finding is not in accordance with research by Zuhri (2014) which states that this variable has a significant effect on CO2 gas emissions. This is because the CO2 gas emissions used in this research come from the energy sector. Based on the publication of the Ministry of Energy and Mineral Resources (ESDM) in 2022, households are in third place as the largest energy consuming sector. Meanwhile, the largest energy users come from the industrial sector. Therefore, the population density variable does not have a significant influence on the CO2 gas emissions variable.

Final energy consumption has a significant relationship to increasing CO2 gas emissions (see Table 4). This finding is in accordance with research by Rahma et al. (2018) which states that this variable has a significant effect on CO2 gas emissions. In the regression equation above, every change in final energy consumption which increases during one year by one thousand Barrels of Oil Equivalent (BOE) will increase CO2 gas emissions by 0.3228 million tonnes assuming other variables are constant.

5.CONCLUSIONS AND SUGGESTIONS

Based on the analysis, 69.94% of the variation in CO2 emissions can be explained by GDP, FDI, population density, and final energy consumption. GDP and final energy consumption have a significant positive impact on CO2 emissions, while FDI and population density do not show significant effects.

In the context of a green economy, it is crucial for the government to utilize renewable energy to reduce CO2 emissions from the energy sector. This can be achieved through the development and broader application of renewable energy technologies and by involving the public in energy efficiency efforts, such as saving electricity and reducing the use of private vehicles. Transitioning to renewable energy and enhancing energy efficiency are essential steps towards achieving a green economy, aiming to reduce environmental impact while supporting sustainable economic growth.

This study highlights the importance of a deep understanding of the factors influencing CO2 emissions to achieve a green economy in Indonesia. Further research is recommended to explore these factors more thoroughly by emission-producing sectors to make a greater contribution to CO2 emission reduction efforts and the attainment of a green economy in Indonesia.

6.IMPLICATIONS AND LIMITATIONS

This research is limited to analyzing fluctuations in Greenhouse Gas Emissions, especially CO2 Gas Emissions in the energy sector. The main limitation of this study lies in its exclusive focus on the energy sector, which causes limitations in providing a comprehensive picture of CO2 emissions across the sector.

The existence of a significant problem in the energy sector, namely the increase in emissions, which has an upward trend every year, is the main reason for choosing a research focus on fluctuations in CO2 emissions in this context. While this research provides valuable insight into changes in greenhouse gas emissions in the energy sector, it does not include a complete picture of all CO2 emissions in other sectors.

Apart from that, time limitations also influenced this research. The data used in the analysis only covers the period from 2000 to 2022. Determination of this time range is based on the availability of accessible data. Therefore, the interpretation of the results of this study only covers that period and further changes in CO2 emissions after 2022 cannot be taken into account.

Nevertheless, the results of this study still provide an important contribution to the understanding of fluctuations in CO2 emissions in the energy sector during the period studied. In an effort to gain a more comprehensive understanding, future research could broaden the scope of sectors and time periods, and consider external factors that may influence overall greenhouse gas emissions.

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