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Article

The Impact of Income Inequality and Energy Consumption Dynamics on Environmental Degradation in Indonesia

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Abstract: Climate change as a form of environmental degradation is an important issue that needs to be addressed to achieve the SDGs. The aim of this research is to analyze the influence of economic growth, energy consumption, income inequality on environmental degradation in Indonesia in the long term and short term and to analyze the suitability of the hypothesis Environmental Kuznets Curve (EKC) is theoretically proven and valid in Indonesia both in the long term and short term. Researchers focus on research in Indonesia because Indonesia is a developing country with significant economic growth, but often there is intensive exploitation of natural resources. The data used in this research is time series data year 1991-2020. In this research, Error Correction Model (ECM) is used to see the influence of independent variables on the dependent variable in the long term and short term, as well as to test hypotheses Environmental Kuznets Curve (EKC), the hypothesis which states there is a relationship between economic growth and environmental quality and depicts an inverted curve is tested using the program Eviews 12. The results of this research are that the economic growth variable has no effect on environmental degradation in Indonesia in the short term, but in the long term economic growth has a significant positive effect on environmental degradation. The energy consumption variable has a positive and significant influence on environmental degradation in Indonesia both in the short and long term. The income inequality variable has no effect on environmental degradation in Indonesia in both the short and long term, there is a negative effect but it is not significant. Environmental Kuznets Curve (EKC) in Indonesia is in accordance with the existing EKC hypothesis. The government needs to implement sustainable development policies and green technology to reduce the negative impact of economic growth and energy consumption on the environment.

Keywords: CO2, Environmental Kuznets Curve, Economic Growth, Energy Consumption, Income Inequality

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1. Introduction

Sustainable Development Goals (SDGs) is a global commitment to achieve sustainable development in various fields, including energy and the environment. One of the SDGs goals related to energy is "Clean and Affordable Energy" (Goal 7), which emphasizes the importance of access to energy services that are easily accessible to all levels of society, reliable, sustainable and modern. These goals include efforts to increase energy efficiency and the share of renewable energy in the energy mix. Apart from that, a goal that is also closely related to energy is "Tackling Climate Change" (Goal 13), which includes efforts to reduce greenhouse gas emissions and strengthen resilience to the impacts of climate change (BAPPENAS, 2023).

Climate change as a form of environmental degradation is an important issue that needs to be addressed to achieve the SDGs. This phenomenon occurs as an impact of economic activities on the environment aimed at economic development. Economic development does not only produce results *output* economy, but also causes

environmental problems such as depletion of natural resources and pollution. Production activities cannot be separated from externalities, especially negative externalities due to the production process which produces waste. This is an indicator of environmental degradation, namely increasing emissions of gases and particulate matter such as dust and so on.

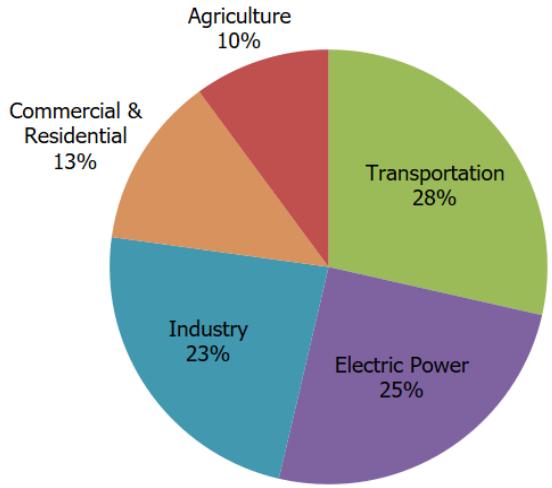

Figure 1. Economic Activities Producing Greenhouse Gas (GHG) Emissions
Source: United States Enviromental Protection Agency (EPA), (2024)

Extreme climate change is influenced by various economic activities that cause Green House Gas (GHG) emissions, such as transportation, industry and energy use. According to Mengpin Ge, Johannes Friedrich, and Leandro Vigna from *World Resources Institute*, the energy sector is a major contributor to GHGs, especially in residential areas. Figure 1 shows that energy consumption for transportation accounts for 28% of GHG, electricity and heat production 25%, and the industrial sector 23%. These emissions include carbon dioxide (CO_2), methane (CH_4), nitrogen dioxida (N_2O), and other fluorinated gases.

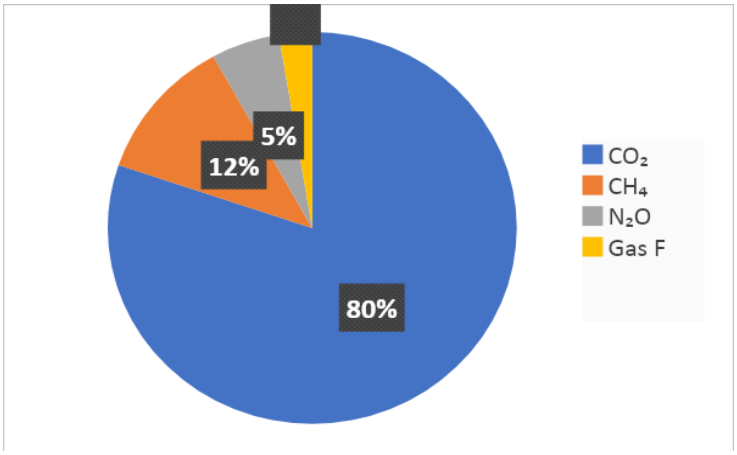

Figure 2. Greenhouse Gas (GHG) Emissions Based on Gas Type
Source: United Nations Framework Convention on Climate Change (UNFCCC), (2022)

UNFCCC (2022) reports that throughout 1990-2021 carbon dioxide (CO_2) was the largest contributor to the total global volume of Green House Gas (GHG) emissions, namely 79.1% in 1990 and in 2021 it increased to 80.1%. *World Energy Outlook (2022*) states that global CO_2 emissions will increase again in 2021 and replace 2010 as the largest increase in CO_2 emissions. The dominance of carbon dioxide (CO_2) emissions makes carbon dioxide (CO_2) the main cause of global warming.

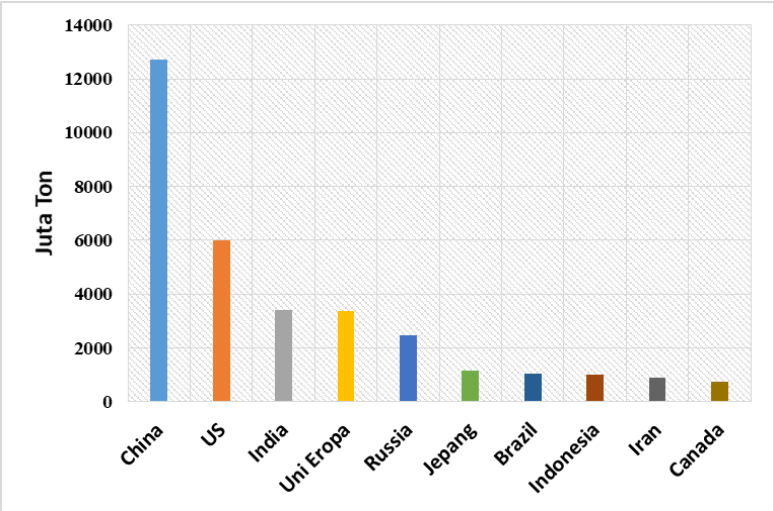

Figure 3. Countries with the Highest Carbon Dioxide Emissions in the World

Source: World Resources Institute, (2023)

Based on Figure 3 together with China, the United States, India, European Union countries, and other countries whose economic growth largely depends on the industrial sector, Indonesia is ranked eighth in emitting carbon dioxide (CO_2) is the largest in the world with 1002.4 MtCO2e. Indonesia is the largest producer of carbon dioxide (CO_2) emissions in the Southeast Asia region. If no action is taken, Indonesia is estimated to lose 2,000 islands by 2030 due to global warming and climate change triggered by increasing CO_2 emissions (Kusumawardani & Dewi, 2020).

The Ministry of Environment and Forestry stated that Indonesia and the world have made efforts to overcome climate change through the Paris Agreement. Indonesia ratified the Paris Agreement with Law Number 16 of 2016 (Pratiwi, 2021). Another effort made by Indonesia is through *Nationally Determined Contribution* (NDC), INDC was submitted in 2015 and revised to *First* NDC in 2016, valid until 2030. In 2021, Indonesia increases the linkage of development and climate goals by including fairer emission reduction targets in *Update* NDC.

Sustainable economic growth is the main target of economic policy in most countries around the world, including Indonesia. However, this can have an impact on global warming and climate change which is now an issue and world concern. Economic development results in increased levels of carbon dioxide (CO_2) emissions and other greenhouse gas (GHG) emissions (Salari, et al., 2021). To improve the economy, developing countries prioritize industrial growth through policies that address economic problems. However, industrialization without long-term planning can damage the environment, with industrial pollution impacting climate change (Soeharjoto et al., 2022).

One way to calculate a country's economic growth is to look at the level of Gross Domestic Product (GDP). In Indonesia's case, rapid economic growth caused an increase in carbon dioxide (CO_2) emissions.

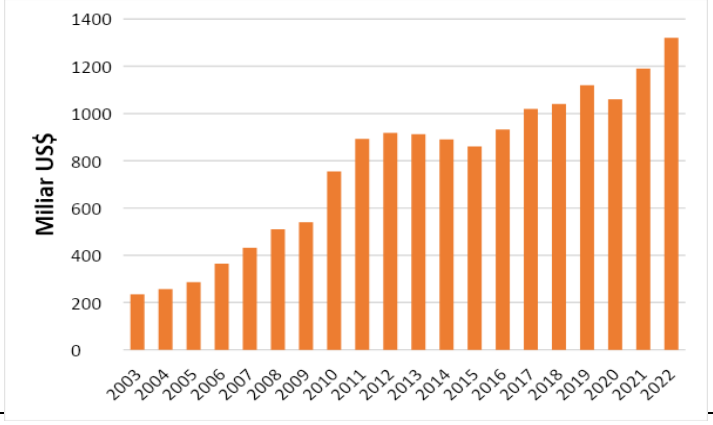

Figure 4. Indonesia's GDP Level 2003-2022 (Billion US$)
Source: World Bank, (2023)

Figure 4 above illustrates changes in Gross Domestic Product (GDP) over the last 20 years, which indicates the magnitude of Indonesia's economic growth rate. *World Bank* reported that over the last 20 years, Indonesia's Gross Domestic Product (GDP) has continued to increase. *World Energy Outlook* (2022) states that in 2021 there will be an increase in CO_2 emissions of 6% compared to 2020 which is in line with the surge *output* global economy by 5.9%. This indicates that there is a strong relationship between carbon dioxide (CO_2) emissions and Gross Domestic Product (GDP) growth since 2010.

The long-term increase in energy consumption in Indonesia also determines economic growth, which indicates the need for energy efficiency (Arifin et al., 2023). Increasing energy consumption from environmentally unfriendly technologies accompanies industrial expansion. In Indonesia, increasing energy use has an impact on carbon dioxide emissions. Coal, oil and natural gas as the main sources of fossil fuels in Indonesia release carbon dioxide when burned, so the increased use of fossil fuels results in higher carbon dioxide emissions.

Apart from an increase in carbon dioxide (CO_2) emissions, Indonesia is also experiencing a significant increase in income inequality even when compared to developing countries around the world. Income inequality in Indonesia increased by around 30% in the 2000-2014 period (Kusumawardani & Dewi, 2020). Based on data from the Fiscal Policy Agency in September 2022, the Gini Ratio was recorded at 0.381, meanwhile, in March 2023 the Gini Ratio increased to 0.388, which means there was an increase 0.007 points (Larasati, 2023). In recent years, income inequality has been assumed to influence carbon dioxide (CO_2) emissions. This happens because high income inequality can trigger higher energy consumption, especially from fossil energy sources, which can then cause an increase in carbon dioxide emissions (Pratiwi, 2021).

Grossman & Krueger's (1991) study was the first study to examine the relationship between the environment and the economy specifically, the relationship between GDP per capita and air pollution forms an inverted U curve. Kuznets Environmental Curve (*Environmental Kuznet Curve* or EKC) is a term used to refer to the research results of Grossman & Krueger (1991). According to this theory, as development progresses, higher economic growth will initially result in more severe environmental damage. However, after a while, there will be a tipping point where higher economic growth will result in less environmental damage.

Research regarding the relationship between economic growth, energy consumption and income inequality on carbon dioxide (CO_2) emissions has been widely carried out and there are varying results. Among them (Fattah et al., 2021) proved in their research that in the shorts and long terms economic growth, energy consumption and economic openness have a significant positive effect on carbon dioxide (CO_2) emissions in Indonesia. However, in his research on Australia, (Shahbaz, et al., 2015) found that although economic growth had a negative effect on CO emissions$_2$, energy consumption has a positive effect on CO emissions$_2$. In addition, it was found that the main factor contributing to reducing CO2 emissions is trade openness. Baek & Gweisah (2013) believe that a more even distribution of income will improve the quality of the environment, and there is a positive correlation between income inequality and environmental damage. Meanwhile, several studies state the opposite. According to Kusumawardani & Dewi (2020), income inequality has a substantial negative impact on carbon dioxide (CO_2) emissions in Indonesia in the short and long term, although the structure of this relationship varies depending on GDP per capita.

Updated analyzes of environmental degradation caused by various economic activities, such as economic growth, energy consumption, and income inequality, are

urgently needed. Research related to environmental degradation in economic development is important to discuss in order to anticipate the link between economic development and environmental degradation, ensure environmental sustainability and increase the effective use of natural resources, direct government policies related to climate change, and achieve *Sustainable Development Goals* (SDGs).

2. Materials and Methods

LITERATURE REVIEW

Environmental Degradation Theory

In economics, externalities are costs or benefits felt by someone where there is no responsibility for the costs or benefits felt by others (Buchanan & Stubblebine, 1962). According to Mankiw (2006), every action a person takes that can have an impact on the welfare of people who do not receive compensation or pay for the perceived impact is considered an externality. According to Schiller (2022), pollution, such as pollution caused by industrial or company activities, is a clear example of negative externalities, this can result in market failure.

1. Economic Growth Theory

The relationship between economic growth (measured by GDP per capita) and environmental quality is explained by *Environmental Kuznets Curve* (EKC). According to Simon Kuznets' theory, there is an inverted U-shaped relationship between income inequality and economic growth. Meanwhile, the EKC explains how a continuous production process will consume massive resources to produce output more, while society and the government are less aware of environmental problems.

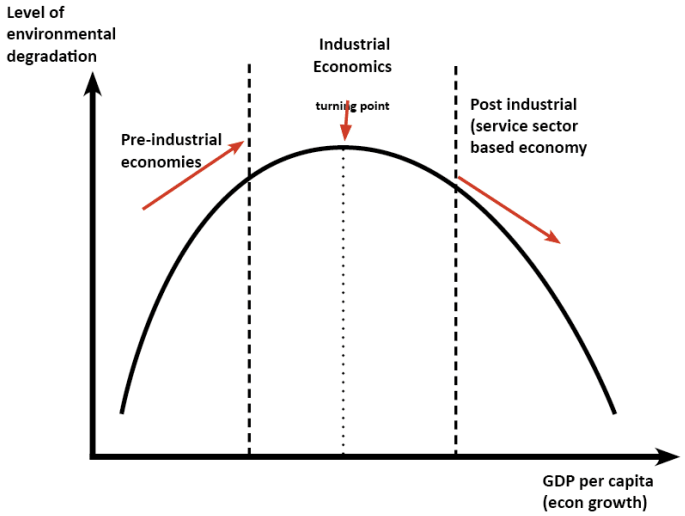

Figure 5. Hypothesis *Environmental Kuznets Curve* (EKC)

Source: Grossman & Krueger, (1991)

Based on Figure 5, the environmental curve adopted from Kuznets theory shows a positive relationship between economic growth and environmental damage in the short term (short term), which shows that increasing environmental damage will follow an increase in economic growth. On the other hand, the relationship between the two is negative over a long period of time (long term), which means that an increase in economic growth will be accompanied by a decrease in environmental damage.

2. Energy Consumption

Energy Economics is a study in economics that analyzes the use and management of energy resources by businesses, governments, and individuals using economic methods (Stevens 2000). Energy consumption supports economic growth and industrialization, but also poses challenges in natural resource management. Changes in energy consumption patterns are a major factor in the modern industrial revolution. According to Mankiw (2006), there is a consumption theory known as the Absolute Income Hypothesis (*Absolute Income Hypothesis*) was developed by John Maynard Keynes in 1930. According to this hypothesis, a person's income level determines their absolute level of expenditure, including energy consumption.

Income Inequality

The Gini coefficient is a measure of income inequality discovered by Corrado Gini, an Italian statistician and sociologist, in 1912. This index has a value between 0 and 1, with 0 indicating perfect equality and 1 indicating perfect inequality. Lower values indicate a more equal distribution of income, while higher values indicate greater inequality.

RESEARCH METHODS

Research Place

Researchers focus on Indonesia because Indonesia is a developing country that has a significant growth rate, aiming to achieve sustainable industrialization. Apart from that, Indonesia also has a significant contribution to total global carbon dioxide (CO_2) emissions.

Data and Data Sources

The type of data used in this research is secondary data. Secondary data in this research is time series data for the period 1991-2020 in Indonesia. Secondary data sources were obtained from *World Bank, Our World In Data, World Inequality Database,* and *World Development Indicators* (WDI) which relates to data on GDP per capita, primary energy consumption per capita, Gini ratio, and carbon dioxide (CO_2) emissions per capita.

Data Analysis

This research uses time series data (*time series*) as a data analysis method. Time series is a collection of observation results (*documentation*) collected over a certain period of time. The data used in this research covers the years 1991 to 2020. In this research, *Error Correction Model* (ECM) is used to see the influence of independent variables on the dependent variable in the long term and short term, as well as to test hypotheses *Environmental Kuznets Curve* (EKC) by using the program *Eviews* 12.

A. Equation Model for *Error Correction Model* (ECM)

This research examines the long-term and short-term effects of GDP per capita, primary energy consumption per capita, and the Gini ratio on CO emissions2 per capita in Indonesia using an analytical approach *Error Correction Model* (ECM). The following is the long-term model equation,

$$CO2_t = a + \beta_1 GDPC_t + \beta_2 PEUC_t + \beta_3 GINI_t + \varepsilon_t$$

Information:

CO2 : Carbon Dioxide Emissions

GDPC : GDP per capita
PEUC : Primary Energy Consumption (*Primary Energy Use*) per capita
GINI : Income Inequality (*Gini Ratio*)
$\beta_{1,2,3}$: Regression coefficient of each independent variable
a : Constant
ε : Residual
t : Time

To estimate the ECM model, the following short-term estimation equation is needed:

$$\Delta CO2_t = a + \beta_1 \Delta GDPC_t + \beta_2 \Delta PEUC_t + \beta_3 \Delta GINI_t + \beta_4 ECT + \varepsilon_t$$

Information:
ΔCO2 : Carbon Dioxide Emissions
ΔGDPC : GDP per capita
ΔPEUC : Primary Energy Consumption per capita
ΔGINI : Income Inequality (*Gini Ratio*)
$\beta_{1,2,3}$: Regression coefficient of each independent variable
a : Constant
ε : Residual
ECT : Residual t-1
t : Time

B. Equation Models for Testing Hypotheses *Environmental Kuznets Curve* (EKC)

Based on the Grossman and Krueger (1995) method, this research tests the hypothesis *Environmental Kuznets Curve* (EKC). The relationship between economic growth and environmental degradation is described in the general equation of Kuznets hypothesis as follows:

$$CO2_t = a + \beta_1 GDPC_t + \beta_2 GDPCS_t + \varepsilon_t$$

Information:
CO2 : Carbon Dioxide Emissions
GDPC : GDP Per Kapita
GDPCS : GDP Per Capita Squared
$\beta_{1,2}$: Regression coefficient of each independent variable
a : Constant
ε : Residual
t : Time

3. Results

A. Test Data Analysis

1. Stationarity Test

Table 1. Stationarity Test Results at level Level and First Difference
Source: Eviews 12, Processed Data, 2024

Variable	ADF t-statistic	Provision	Prob	Provision	Conclusion
Level					

Variable	ADF t-statistic	Provision	Prob	Provision	Conclusion
CO2	-1.062208	< -2.998064	0.7125	< 0.05	Not Stationary
GDPC	0.922090	< -2.967767	0.9944	< 0.05	Not Stationary
PEUC	-3.666469	< -2.998064	0.0121	< 0.05	Stationary
GINI	-1.660840	< -2.967767	0.4398	< 0.05	Not Stationary
First Difference					
D(CO2)	-5.099745	< -2.998064	0.0005	< 0.05	Stationary
D(GDPC)	-3.344167	< -2.971853	0.0222	< 0.05	Stationary
D(PEUC)	-4.490530	< -2.971853	0.0014	< 0.05	Stationary
D(GINI)	-4.554384	< -2.971853	0.0012	< 0.05	Stationary

After testing at level *first difference*, all variables, namely carbon dioxide emissions (CO2), economic growth (GDPC), energy consumption (PEUC), and income inequality (GINI) become stationary. This is indicated by the ADF t-statistic value which is smaller than the critical value and the probability is smaller than 0.05 for all these variables. Thus, it can be concluded that the variables CO2, GDPC, PEUC, and GINI do not have a unit root or are stationary at the first derivative level (*first difference*).

2. Cointegrity Test

Table 2. Residual Regression Stationarity Test Results at Level Level
Source: Eviews 12, Processed Data, 2024. Attachment.

Variable	ADF t-statistic	Provision	Prob	Provision	Conclusion
Level					
ECT	-4.741938	< -2.967767	0.0007	< 0.05	Stationary

Based on the results of the regression residual stationarity test at the level presented in Table 2, it was found that the ECT variable (*Error Correction Term*) has ADF *t-statistic* of -4.741938 with a probability of 0.0007. Thus, it can be concluded that there is cointegration between the variables in the model

B. Test *Error* Correction *Model* (ECM)

1. Test *Error Correction Model* (ECM) Short Term

Table 3. Short Term ECM Estimation Results
Source: Eviews 12, Processed Data, 2024. Attachment.

Variable	Coefficient	Prob.
C	0.009669	0.3291
D(GDPC)	-7.61E-05	0.4402
D(PEUC)	0.069587	0.0000
D(GINI)	-0.191878	0.5936
ECT(-1)	-0.985445	0.0000

Based on Table 3 above, the results of the short-term equation are as follows:

$$D(CO2)_t = 0.009669 - 0.0000761D(GDPC)_t + 0.069587D(PEUC)_t - 0.191878D(GINI)_t - 0.985445ECT(-1) + \varepsilon_t$$

In the short-term ECM test results, there are several important findings that can be interpreted, namely in the short term:

a. The constant coefficient (C) of the short-term equation is 0.009669, indicating a change in CO2 emissions of 0.009669 tons per capita without changes in the independent variables.
b. The GDP per capita coefficient (GDPC) is -0.0000761, indicating a negative relationship between GDP per capita and CO2 emissions of 0.0000761 tons per capita.
c. The primary energy consumption coefficient per capita (PEUC) is 0.069587, indicating a positive relationship between primary energy consumption per capita and CO2 emissions of 0.069587 tons per capita.
d. The income inequality coefficient (GINI) is -0.191878, indicating a negative relationship between income inequality and CO2 emissions of 0.191878 tons per capita.
e. The Error Correction Term (ECT) coefficient is -0.985445, indicating that approximately 98.54% of the short-term imbalance will be corrected towards long-term balance in the next period in the model equation.

2. Test *Error Correction Model* (ECM) *Term* Long

Table 4. Long Term ECM Estimation Results
Source: Eviews 12, Processed Data, 2024. Attachment.

Variable	Coefficient	Prob.
C	0.199970	0.2606
GDPC	0.000153	0.0000
PEUC	0.054994	0.0000
GINI	-0.444510	0.1513

Based on Table 4 above, the results of the long-term equation are as follows:

$$CO2_t = 0.199970 + 0.000153GDPC_t + 0.054994PEUC_t - 0.444510GINI_t + \varepsilon_t$$

In the long-term ECM test results, there are several important findings that can be interpreted, namely in the long term:

a. The constant coefficient (C) value of 0.199970 indicates the basic level of CO2 emissions when all independent variables are constant or have a value of zero.
b. The GDPC coefficient value of 0.000153 shows a positive relationship between GDP per capita and CO2 emissions, with every one unit increase in GDP per capita increasing CO2 emissions by 0.000153 tons per capita.
c. The PEUC coefficient value of 0.054994 indicates that primary energy consumption per capita is positively correlated with CO2 emissions, where every increase of one unit of primary energy consumption per capita increases CO2 emissions by 0.054994 tons per capita.
d. The GINI coefficient value -0.444510 shows a negative relationship between income inequality and CO2 emissions, where increasing income inequality tends to reduce CO2 emissions by 0.444510 tons per capita.

C. Hypothesis Testing

1. Uji Partial (Uji t)

Table 5. t Test Results in the Short Term
Source: Eviews 12, Processed Data, 2024. Attachment.

Variable	t-statistic	Prob.
D(GDPC)	-0.784906	0.4402
D(PEUC)	8.529388	0.0000
D(GINI)	-0.540827	0.5936
ECT(-1)	-5.197094	0.0000

Based on the results of the partial test (t test) in the ECM model for the short term in Table 5, it can be interpreted that:

b. GDPC has a negative but not significant effect at the 5% level on CO2 emissions per capita in the short term (t-statistic = -0.784906, probability = 0.4402).
c. PEUC has a positive and significant influence at the 5% significance level on CO2 emissions per capita in the short term (t-statistic = 8.529388, probability = 0.0000).
d. GINI has a negative but not significant effect at the 5% level on CO2 emissions per capita in the short term (t-statistic = -0.540827, probability = 0.5936).
e. ECT is highly significant at the 5% significance level, indicating the existence of a mechanism of readjustment to long-term equilibrium (t-statistic = -5.197094, probability = 0.0000).

Table 6. Long Term t Test Results
Source: Eviews 12, Processed Data, 2024. Attachment.

Variable	t-statistic	Prob.
GDPC	5.094032	0.0000
PEUC	13.41340	0.0000
GINI	-1.478515	0.1513

Based on the results of the partial test (t test) in the long-term ECM model in Table 6, it can be interpreted that:

a. GDPC has a t-statistic of 5.094032 with a probability of 0.0000 at a significance level of 5%, indicating a positive and significant influence of GDP per capita on CO2 emissions per capita in the long term.
b. PEUC has a t-statistic of 13.41340 with a probability of 0.0000 at a significance level of 5%, indicating a positive and significant influence of primary energy consumption per capita on CO2 emissions per capita in the long term.
c. GINI has a t-statistic of -1.478515 with a probability of 0.1513, indicating a negative influence of income inequality on CO2 emissions per capita, but it is not significant at the 5% level in the long term.

In the partial test, the variables PEUC and ECT have a significant effect on the dependent variable in the short term, indicating the importance of energy consumption and long-term balance adjustment mechanisms. In the long run, GDPC and PEUC also have a significant effect on the dependent variable, highlighting the role of economic growth and energy consumption as crucial factors. GINI is not significant in either the short or long run, indicating that income inequality does not significantly affect this model.

2. Simultaneous F Test

Table 7. F Test Results in the Short Term
Source: Eviews 12, Processed Data, 2024. Attachment.

	Results	Provision
F-statistic	30.78534	> 2.76
Prob (F-statistic)	0.000000	< 0.05

Based on the short-term ECM regression results in Table 7, the simultaneous test or F test shows significant results at the 5% significance level. In the short term, this shows that the regression model in the short term is statistically significant, meaning that the independent variables jointly influence the dependent variable.

Table 8. F Test Results in the Long Term
Source: Eviews 12, Processed Data, 2024. Attachment.

	Results	Provision
F-statistic	810.3011	> 2.96
Prob (F-statistic)	0.000000	< 0.05

Based on the long-term ECM regression results in Table 8, the simultaneous test or F test shows significant results at the 5% significance level. This shows that the regression model in the long term is very statistically significant, meaning that the independent variables together have a very strong influence on the dependent variable.

Thus, in both the short and long term, the F test results indicate that the independent variables together have a significant influence on the dependent variable.

3. Coefficient of Determination Test (R^2)

Table 9. Results of the Coefficient of Determination in the Short Term
Source: Eviews 12, Processed Data, 2024. Attachment.

	Results
R-squared	0.836892
Adjusted R-squared	0.809707

In Table 9, the short-term ECM regression results show that the coefficient of determination (R-squared) is 0.836892, indicating that around 83.69% of the CO2 variation can be explained by the independent variables. Adjusted R-squared of 0.809707 indicates that around 80.97% of the variation in CO2 can still be explained after adjusting for the number of independent variables in the model. This regression model is effective in explaining the relationship between these variables in the short term.

Table 10. Results of the Coefficient of Determination in the Long Term
Source: Eviews 12, Processed Data, 2024. Attachment.

	Results
R-squared	0.989418
Adjusted R-squared	0.988197

In Table 4.18, the ECM regression results show a coefficient of determination (R-squared) of 0.989418, indicating that around 98.94% of the variation in CO2 can be explained by the independent variables in the model. Adjusted R-squared of 0.988197 indicates that around 98.82% of the variation in CO2 can still be explained after adjusting for the number of independent variables. This regression model is very strong in explaining the relationship between independent and dependent variables in the long term.

D. *Environmental Kuznets Curve* (EKC)

Table 11. Estimated Results Enviromental Kuznets Curve (EKC)
Source: Eviews 12, Processed Data, 2024. Attachment.

Variable	Coefficient	Prob.
C	-0.747350	0.0524
GDPC	0.001359	0.0001
GDPCS	-1.63E-07	0.0052

Based on the estimation results to prove the hypothesis *Environmental Kuznets Curve* (EKC), then the equation model is obtained as follows:

$$CO2_t = -0.747350 + 0.001359GDPC_t - 0.000000163GDPCS_t + \varepsilon_t$$

In these results, several important findings were found. The GDPC coefficient of 0.001359 (p=0.0001) shows a significant positive relationship between increasing GDP and CO2 emissions in the early stages of economic growth. The GDPCS coefficient of -1.63E-07 (p=0.0052) shows a significant negative relationship, indicating that at higher income levels, CO2 emissions tend to decrease. The constant coefficient (C) of -0.747350 (p=0.0524) indicates the starting point for CO2 emissions without the influence of other variables. These results are consistent with the EKC hypothesis, which states that initial economic growth increases pollution, but at higher income levels, pollution decreases. This model explains 90.51% of the variation in CO2 emissions (R-squared = 0.905059), demonstrating good fit, with the F test confirming the overall significance of the model and the validity of the EKC patterns in this analysis

4. Discussion

The Effect of Economic Growth on Environmental Degradation in Indonesia

Based on the analysis results *Error Correction Model* (ECM) which has been carried out by researchers, the results obtained are that in the short term the economic growth variable does not have a significant effect on environmental degradation. Meanwhile, in the long term, economic growth has a significant effect on environmental degradation. This is in accordance with the theory put forward by W. W. Rostow (1960) which outlines the stages of economic development, starting from traditional society to high mass consumption. In the early stages of growth, a country will focus on the primary sector which may not have a major impact on carbon dioxide emissions, but as countries transition towards industrialization, carbon dioxide emissions increase significantly due to industrial and manufacturing activities (Arsyad 1999).

These results are strengthened by research conducted by *Climate Change* (2007) where global greenhouse gas emissions, especially carbon dioxide emissions, began to appear to increase significantly starting from the industrial revolution in the 18th century (Forster et al. 2007). The results of this research are supported by previous research conducted by Azhima Muhammad Fattah, Jaka Aminata, Indah Susilowati, and Arief Pujiyono (2021). which states that in the short term only economic openness and energy consumption have a significant positive effect on carbon dioxide (CO2) emissions, while economic growth does not show a significant effect. However, over time, in the long term, the three independent variables used, namely economic openness, energy consumption, and economic growth, have a significant positive effect on carbon dioxide emissions, which shows that economic development directly impacts the level of environmental degradation (Fattah et al., 2021)

The Influence of Energy Consumption on Environmental Degradation in Indonesia

Based on the analysis results *Error Correction Model* (ECM) energy consumption shows a consistent influence on environmental degradation in the short and long term, namely a significant positive effect. This is in line with data from the

Ministry of Energy and Mineral Resources (2019), that one of the biggest causes of environmental degradation is carbon dioxide (CO2) emissions produced by energy consumption which continues to increase along with the increase in energy demand. The results of this research are in line with previous research conducted by Monica R. K., Ahmad K, and Ari T. (2023), in their research the results showed that the energy consumption variable had a significant positive effect in both the short and long term in Indonesia from 1980 to 2019 (Gift et al., 2023).

This research is supported by an international literature study by K. Elfaki & U. Heriqbaldi (2023) entitled "Analyzing the Moderating Role of Industrializa-tion on the Environmen-tal Kuznets Curve (EKC) in Indonesia: What Are the Contributions of Financial Development, Energy Consumption, and Economic Growth?" stated that energy consumption was found to have a significant impact on carbon dioxide emissions in Indonesia. Other research that also supports this research, namely Santi & Sasana (2021) which shows that energy consumption significant positive effect on improvement carbon footprint. Amalina, Wahyudi & Citpawaty (2023) in their research found that energy consumption has a significant positive influence in both the short and long term on carbon dioxide emissions in Indonesia.

The Effect of Income Inequality on Environmental Degradation in Indonesia

Based on the analysis results *Error Correction Model* (ECM) which has been carried out by researchers, the results obtained are that in the short term the income inequality variable does not have a significant effect on environmental degradation. Likewise, in the long term, income inequality does not have a significant effect on environmental degradation. Several studies show that income inequality does not always have a significant effect on environmental degradation because other factors such as environmental policy, technology and economic structure are more dominant. High-income groups may adopt sustainable consumption practices, while regulation and resource management can also reduce the negative impacts of income inequality.

This is in line with international literature studies by Panji Kusuma Prasetyanto & Farmila Sari (2021). Income inequality in Indonesia is not significant for environmental degradation in both the short and long term, although the increase can be related to increased production waste, water consumption and loss of biodiversity. This research is also in accordance with previous findings that income inequality has a negative impact on environmental degradation. For example, research by Deni Kusumawardani & Ajeng K. Dewi (2020) shows that income inequality significantly influences carbon dioxide emissions in Indonesia, although there are differences in significance, this could be caused by differences in the research time period used, so that the influence given not significant.

Hypothesis *Environmental Kuznets Curve* (EKC) in Indonesia

Based on the results of the regression analysis carried out by researchers, the results showed that the economic growth variable had a significant positive effect on environmental degradation, while the quadratic economic growth variable had a significant negative effect on environmental degradation. These findings are in accordance with the provisions of the EKC hypothesis where according to the Kuznets hypothesis, it is projected that economic growth will have a positive value and squared economic growth will be negative, resulting in an inverted U-shaped EKC curve. So, the findings are in accordance with the research hypothesis, namely *Environmental Kuznets Curve* (EKC) is theoretically proven in research results and applies in Indonesia both in the short and long term.

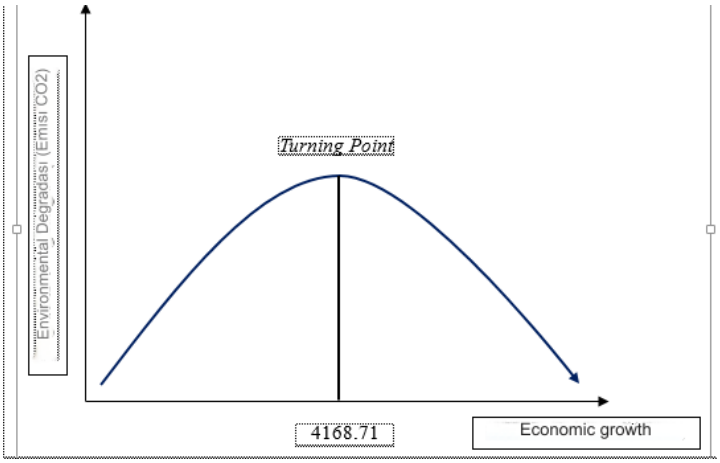

Figure 6. Illustration *Environmental Kuznets Curve* (EKC) in Indonesia
Source: Researcher, 2024

Indonesia has not yet reached the EKC turning point with economic growth still below US$4168.71. However, government efforts, including commitments in the Paris Agreement on Climate Change and NDCs, show the potential to achieve the EKC in the future. This is in line with international literature studies by Yogi Sugiawan & Shunsuke Managi (2016). In addition, this research is also supported by a review of empirical studies regarding the hypothesis *Environmental Kuznets Curve* (EKC) in China by Mahmood et al. (2023).

5. Conclusion

The economic growth variable has no effect on environmental degradation in Indonesia in the short term, but in the long terms economic growth has a significant positive effect on environmental degradation. The energy consumption variable has a positive and significant influence on environmental degradation in Indonesia both in the short and long term. The income inequality variable has no effect on environmental degradation in Indonesia, both in the short and long term. The test results stated that there was a negative influence but it was not significant. *Environmental Kuznets Curve* (EKC) in Indonesia is in accordance with the existing EKC hypothesis.

Suggestion

Based on the results and conclusions above, researchers can provide recommendations or suggestions. For the government, the government must focus on implementing sustainable development policies by considering the economic impact, energy consumption and income inequality on the environment. Encouraging green technology and renewable energy can efficiently reduce the negative impact of economic growth and energy consumption on the environment. It is hoped that the findings of this research will provide valuable insights for policy development in Indonesia, examine the relationship between economic development and environmental quality, and support the country's goals in achieving sustainable development. Future researchers need to continue to explore the relationship between economic growth and environmental degradation, taking into account other potential factors influencing environmental degradation and including more recent time periods to observe changes over time.

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