SINOMICS JOURNAL
International Journal of Social Science, Education, Communication and Economics
ISSN (e): 2829-7350 | ISSN(p): 2963-9441

The Influence of GDP per Capita, Income Inequality, and Population on CO2 Emission (Environmental Kuznet Curve Analysis in Indonesia)

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Abstract

This study aims to prove the environmental kuznet curve (EKC) hypothesis in Indonesia and the effect of GDP per capita, income inequality, and population on CO2 emissions. This research uses a descriptive quantitative method. The data used is the time series from 1990-2021. The data analysis method used is the error correction model (ECM) to see the effect of the independent variables on the dependent variable in the short term and long term. The results of this study indicate that the EKC hypothesis is not proven in Indonesia either in the short term or in the long term. GDP per capita has a significant positive effect on CO2 emissions both in the short term and long term. Income inequality has no significant positive effect on CO2 emissions in the short term and no significant negative effect in the long term. The population has no significant negative effect on CO2 emissions in the short term and has a significant positive effect in the long term.

Keywords *EKC, CO2 Emissions, GDP per Capita, Income Inequality, Population*

INTRODUCTION

Economic development is an issue that is often raised along with rapid economic growth. The main indicator that characterizes economic growth is Gross Domestic Product (Grishin et al., 2019). GDP is the value of final goods and services produced by a country in a certain period time. Over the past few years, Indonesia has continued to experience positive economic growth. Based on data published by Badan Pusat Statistik (2019), Indonesia experienced economic growth of 5.03% in 2016, continued to grow 5.07% in 2017, and 5.17% in 2018. Despite negative growth in 2020 due to the Covid-19 pandemic, economic recovery was able to increase economic growth drastically in 2021.

Economic growth is the main determinant of a country's success, but on the other hand, it becomes a problem of environmental quality. Efforts to increase economic growth require economic activity and energy consumption which cause air pollution (Sukono et al., 2019). Economic activities and energy consumption, such as industry, settlements, and transportation, contribute 60% to CO2 emissions (Nikensari et al., 2019). This proves that an increase in GDP as an effort to increase economic growth causes CO2 emissions. Indonesia continues to experience increasing CO2 emissions and is ranked 10th as the country with the largest CO2 emissions in the world. Based on data from Our World in Data Indonesia produces CO2 emissions of 567254800 tonnes in 2017, increased to 603657100 tonnes in 2018, and increased again in 2019 to 659435700 tonnes.

Indonesia's economic growth continues to increase but is accompanied by an increase in CO2 emissions indicating that economic development has not been achieved. Economic development is measured by economic growth and income inequality (Amri, 2017). Economic growth that continues to increase does not guarantee a reduction in the level of income inequality in a country. Based on a survey conducted by the International NGO

Forum of Indonesia (INFID) it was reported that the richest 1% of people in Indonesia control 49.3% of national wealth, and even the richest 10% control 75.7% of national wealth (Mawardi, 2018). In developing countries, the main focus of economic development is still based on increasing economic growth alone, causing exploitation of natural resources and causing CO2 emissions.

There are two streams of research on growth, inequality, and the environment. First, the relationship between economic growth and environmental quality can use the environmental kuznet curve (EKC). EKC shows an inverted U-shaped relationship between income and CO2 (Grossman & Krueger, 1991). Second, the relationship between income inequality and environmental quality uses the EKC approach by controlling income inequality using the gini index (Belaïd et al., 2020).

To increase GDP, the population is needed as a development actor. However, the rapid increase in population causes a decrease in environmental quality. The ever-increasing population has a negative impact on Natural Resources because it requires greater resources and the impact of environmental pollution due to development (Oktavia et al., 2021). A growing population will increase the use of fossil fuels, transportation will continue to increase, and industrial activities will increase to meet people's demands. These activities cause CO2 emissions.

This research focuses on the problem of GDP per capita which continues to increase in Indonesia, the existence of income inequality, and the population on CO2 emissions. This research connects three aspects of sustainable development, namely economic, social, and environmental. The research analyzes the effect of GDP per capita, income inequality, and population on CO2 emissions in the short and long term and proves the EKC hypothesis in Indonesia.

LITERATURE REVIEW

Economic growth

Kuznets said that economic growth is an increase in the long-term capability of the country concerned to provide economic goods to its population (Todaro, 2000). The increase in capacity stems from technological, ideological, and institutional advances. Economic growth is one of the essential parameters for the success of economic development. Economic growth is also interpreted as an increase in output per capita in the long term and is a measure of the success of development (Affandi et al., 2021).

In general, economic growth is measured using the Gross Domestic Product (GDP) in a region. GDP is defined as the increase in the value of all goods and services produced in a region within a certain period of time. GDP is an important indicator for knowing the condition of the economy at a certain period time in a region because it calculates the value added and the value of final goods and services produced by economic units in a certain area (Syari et al., 2017).

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International Journal of Social Science, Education, Communication and Economics
ISSN (e): 2829-7350 | ISSN(p): 2963-9441

Income Inequality

Income inequality is defined as a condition of inequality in the distribution of income received by the community. According to Todaro & Smith (2011) income inequality is the unequal distribution of national income among various households within a country. The theory of income inequality begins with the emergence of the inverted U-shaped hypothesis proposed by Simon Kuznets. The theory of Simon Kuznets (1995) states that an inverted U-shaped represents a condition of unequal income distribution when economic development is just starting, but after economic development reaches a certain point income distribution will be more even (Fauzia & Suseno, 2017).

Population

Population is the total number of people living at a certain time and area which is the result of demographic processes, namely fertility, migration, and mortality (Rusli, 2012). The population is an important component of economic activity (such as labor or expertise) so it becomes a determining factor for development. Rapid population growth causes great pressure on natural resources such as food needs, clean water, and housing (Akhirul et al., 2020). Population theory was first developed by Thomas Robert Malthus. According to Malthus's view, humans need food to live, but the rate of population growth is much faster than the rate of food growth. According to Malthus, population growth increases in geometric progression, while food supplies increase arithmetically (Pieris, 2015).

Environmental Kuznet Curve (EKC)

Environmental Kuznet Curve is a concept that describes the correlation of income per capita with income inequality in an inverted U-shape. According to the EKC theory developed by Kuznet, there is a positive correlation between economic growth and income inequality, but the correlation between the two becomes negative in the long run (Kuznets, 1995). This thinking forms the basis of the same analogy that economic growth at the beginning of development will result in environmental degradation, but after becoming a turning point, increasing economic growth will increase the need for better environmental quality (Grossman & Krueger, 1991).

METHOD

The scope of research

This research uses a type of quantitative research with a descriptive approach. The independent variables of this study are GDP per capita, income inequality as measured by the gini ratio, and population. The dependent variable in this study is CO2 emissions as a proxy for environmental degradation. The scope of this research is the State of Indonesia during the 1990-2021 period. The data in this study are time series data

Data analysis

Stationarity Test

The time series data approach requires data that has no unit roots (random walk) or stationary data. So to estimate the data, stationarity testing is needed or known as the unit root test. The stationarity test in this study used the Augmented Dickey-Fuller (ADF) method. To find out whether the tested data has a unit root or not, a comparison is made between the ADF t-statistic and the MacKinnon critical value.

Integration Test

Integration testing is carried out if the stationary test on the observed variables shows results that are not stationary. The purpose of the integration test is to see to what degree the data will be stationary. In this study, the integration test used was the first-difference data using the ADF test.

Cointegration Test

The cointegration test aims to see the stability between two or more variables in the long run. This study uses the Engel-Granger (EG) test to detect cointegration. The Engle - Granger test can determine the cointegration of the stationarity test on the residual value.

Data analysis method

The analytical method used in this study is the error correction model (ECM). ECM can report many variables when analyzing variables in the long and short term, examine the consistency of empirical models with econometric theory, and solve problems with non-stationary time series variables. This research uses Domowitz El Domowitz ECM.

Research Model

The research model for analyzing the environmental kuznet curve (EKC) hypothesis in this study is as follows:

$CO2 = \beta 0 + \beta 1GDP + \beta 2GDP2 + \nu t$

Where:

CO2	: CO2 Emission
GDP	: GDP per Capita
Vt	: Error random
β0	: Constant
β1 dan β2	: Coefficients

The specifications for the analysis model to see the effect of GDP per capita, income inequality, and population on CO2 emissions are as follows:

$CO2 = \beta 0 + \beta 1GDP_t + \beta 2GR_t + \beta 3P_t + \epsilon$

Where:

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International Journal of Social Science, Education, Communication and Economics
ISSN (e): 2829-7350 | ISSN(p): 2963-9441

CO2 : CO2 Emission
GDP : GDP per Capita
GR : Gini Ratio (income inequality)
P : Population (total population)
β0 : Constant
β1,β2,β3 : Coefficient
ϵ : error term

RESULTS AND DISCUSSION

Results of Data Analysis

Stationarity Test

Table 1 Stationarity Test Results

Variable	ADF Test Value	McKinnon critical value			Prob.	Ket
		1%	5%	10%		
CO2	-0.492203	-3.661661	-2.960411	-2.619160	0.8797	Not Stationary
GDP	0.248447	-3.661661	-2.960411	-2.619160	0.9714	Not Stationary
Inequality	-0.981690	-3.661661	-2.960411	-2.619160	0.7473	Not Stationary
Population	-1.889931	-3.737853	-2.991878	-2.635542	0.3311	Not Stationary

Based on the results of the stationarity test, it shows that all variables in this study are not stationary. This can be seen from the ADF test value on the CO2 variable of -0.492203, the GDP per capita variable of 0.248447, the inequality variable -0.981690, and the population variable of -1.889931 which is less than McKinnon's critical value at various levels of confidence (1%, 5%, 10%). In addition, the probability value for all variables is greater than the value α 5% = 0.05. Thus, the results of all variables in this study are not stationary at this level.

Integration Test

Table 2 Integration Test Results

Variable	ADF Test Value	McKinnon critical value			Prob.	Ket
		1%	5%	10%		
CO2	-5.405547	-3.679322	-2.967767	-2.622989	0.0001	Stasionery
GDP	-4.314652	-3.670170	-2.963972	-2.621007	0.0020	Stasionery
Inequality	-4.396564	-3.670170	-2.963972	-2.621007	0.0016	Stasionery
Population	-3.036626	-3.699871	-2.976263	-2.627420	0.0441	Stasionery

Based on the results of the integration test at the first difference level, shows that all the variables in this study are stationary. This can be seen from the ADF test value on the CO2 emission variable of -5.405547, the GDP per capita variable of -4.314652, the income

inequality variable of -4.396564 greater than McKinnon's critical value at various levels of confidence (1%, 5%, 10%). Meanwhile, the population variable shows stationary at 5% significance. In addition, the probability value for all variables is smaller than the value α 5% = 0.05. Thus, all variables in this study are stationary at the first difference level.

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Cointegration Test

Table 3 Cointegration Test Results

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.507542	0.0012
Test critical values:	1% level	-3.661661	
	5% level	-2.960411	
	10% level	-2.619160	

Based on the cointegration test results above, the probability value of 0.0012 is less than the α 5% (0.05). So that the equation being tested has an equilibrium relationship in the long term. This means that the estimation model can be further interpreted.

EKC Estimation Results

Short-term

Tabel 4 Short- Term EKC Estimation Results

Variable	Coefficient	Std. Error	t-statistics	Prob.	R2
C	7246965	4549930	1.592764	0.1229	0.409946
D(GDP)	84833.19	36512.40	2.323408	0.0279	
D(GDP2)	-3.629131	6.585474	-0.551081	0.5861	
ECT (-1)	-0.213442	0.099488	-2.145403	0.0411	

The environmental kuznets curve (EKC) hypothesis requires that the coefficient on the variable GDP per capita has a positive sign and the coefficient on the variable GDP per capita squared has a negative sign. Based on the results of testing the EKC hypothesis in this study, it shows that the variable GDP per capita has a coefficient of 84833.19 and the variable GDP per capita squared has a coefficient of -3.629131.

Long-term

Table 5 Long-Term EKC Estimation Results

Variable	Coefficient	Std. Errod	t-statistics	Prob.	R2
C	1.59E+08	31045402	5.107558	0.0000	0.923648
GDP	109435.9	37220.10	2.940237	0.0064	
GDP2	-0.735142	7.960460	-0.092349	0.9271	

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International Journal of Social Science, Education, Communication and Economics
ISSN (e): 2829-7350 | ISSN(p): 2963-9441

Based on the results of long-term estimation, the coefficient value of the variable GDP per capita is positive, which is equal to 109435.9 and the coefficient value of GDP per capita squared is negative, which is equal to -0.735142.

T-Test

Short Term Models

Table 7 T-Test of the EKC Hypothesis Model in the Short Term

Variable	t-statistics	t-table	Prob.	Information
GDP	2.323408	1.70113	0.0279	significant
GDP2	-0.551081	1.70113	0.5861	Not Significant
ECT	-2.145403	1.70113	0.0411	significant

The results of the calculation of the t-test show that the statistical value of GDP is 2.323408 > t-table value of 1.70113 with a probability of 0.0279 less than alpha 5% (0.05), then the variable GDP per capita has a real or significantly positive effect on CO2 emissions in Indonesia. Meanwhile, the t-statistic value of GDP per capita squared is -0.551081 < t-table 1.70113 with a probability of more than alpha 5% (0.005), then GDP per capita squared has a negative and insignificant effect on CO2 emissions in Indonesia.

Long Term Models

Table 7 T-Test of the EKC Hypothesis Model in the Long Term

Variable	t-statistics	t-table	Prob.	Information
GDP	2.940237	1.70113	0.0064	significant
GDP2	-0.092349	1.70113	0.9271	Not Significant

The results of the t-test calculation show that the statistical value of GDP per capita is 2.940237 > t-table value of 1.70113 with a probability of 0.0064 less than alpha 5% (0.05), then the GDP per capita variable has a real or significant positive effect on CO2 emissions in Indonesia. Meanwhile, the t-statistic value of GDP per capita squared is -0.092349 < t-table 1.70113 with a probability of more than alpha 5% (0.005), then GDP per capita squared has a negative and insignificant effect on CO2 emissions in Indonesia.

F-Test

Short Term Models

Table 8 F-test of the EKC Hypothesis Model in the Short Term

f-table	f-statistics	Prob.	Information
3,34	6.252853	0.002307	significant

The results of the calculation of the f-test show that the value of the f-statistic is 6.252853> f-table 3.34 with a probability of 0.002307 less than the alpha value of 5% (0.05) so can be concluded that the variables GDP per capita and GDP per capita squared together the same significant effect on CO2 emission variables.

Long Term Models

Table 9 F-test of the EKC Hypothesis Model in the Long Term

f-table	f-statistics	Prob.	Information
3,34	175.4103	0.000000	significant

The results of the calculation of the f-test in the table above show that the value of the f-statistic is 175.4103 > f-table 3.34 with a probability of 0.000000 less than the alpha value of 5% (0.05), so it can be concluded that the variables GDP per capita and GDP per capita squared together have a significant effect on the CO2 emission variable.

Determination Coefficient Test (R2)

Regression results in the short term obtained an R2 value of 0.409946. That is, GDP per capita and GDP per capita squared together can explain 40.9946% of CO2 emissions. While the remaining 59.0054% is explained by other variables outside the research model. The long-term regression results obtained an R2 value of 0.923648. That is, GDP per capita and GDP per capita squared together can explain 92.3648% of CO2 emissions. While the remaining 7.6352% is explained by other variables outside the research model.

Estimating the Influence of GDP per Capita, Income Inequality, and Total Population on CO2 Emission di Indonesia

Short-term

Table 10 Short Term Estimation Results

Variable	Coefficient	Std. Error	t-statistics	Prob.	R2
C	62045241	77047907	0.805281	0.4280	0.593224
GDP	40630.62	17211.78	2.360629	0.0260	
Inequality	698885.5	3124697.	0.223665	0.8248	
Population	-16.79596	25.13333	-0.668274	0.5095	
ECT	-0.832239	0.195686	-4.252934	0.0002	

Long-term

Table 11 Long Term Estimation Results

Variable	Coeffisient	Std. Error	t-statistik	Prob.	R2
C	-3.19E+08	1.38E+08	-2.319187	0.0279	0.983160
GDP	50154.20	12143.09	4.130268	0.0003	
Inequality	-4716203.	2911658.	-1.619765	0.1165	

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International Journal of Social Science, Education, Communication and Economics
ISSN (e): 2829-7350 | ISSN(p): 2963-9441

Population	3.344576	0.395793	8.450317	0.0000

Based on the estimation results, the estimated results of the regression equation are as follows:

CO2 = -3.19 + 50154.20GDPt - 4716203GRt + 3.344576Pt

T-Test

Short-term

Table 12 Short Term t-test Results

Variable	t-statistics	t-table	Prob.	Information
GDP	2.360629	1.70329	0.0260	Significant
Inequality	0.223665	1.70329	0.8248	Not Significant
Population	-0.668274	1.70329	0.5095	Not Significant
ECT	-4.252934	1.70329	0.0002	Significant

The results of the t-test calculation show that the t-statistic value of GDP per capita is 2.360629 > t-table value of 1.70329 with a probability of 0.0260 less than alpha 5% (0.05), so in the short-term the GDP per capita variable has a real or significant positive effect on CO2 emissions in Indonesia.

The t-statistic value of income inequality is 0.223665 < t-table value 1.70329 with a probability of 0.8248 more than alpha 5% (0.05), so in the short-term the income inequality variable has no significant positive effect on CO2 emissions in Indonesia.

The t-statistic value of the population is -0.668274 < t-table value 1.70329 with a probability of 0.5095 more than alpha 5% (0.05), so in the short-term the variable population has a negative and insignificant effect on CO2 emissions in Indonesia.

Long-term

Table 14 Long Term t-test Results

Variable	t-statistics	t-table	Prob.	Information
GDP	4.130268	1.70329	0.0003	Significant
Inequality	-1.619765	1.70329	0.1165	Not Significant
Population	8.450317	1.70329	0.0000	Significant

The results of the t-test calculation show that the t-statistic value of GDP per capita is 4.130268 > the t-table value of 1.70329 with a probability of 0.0003 less than alpha 5% (0.05), so in the long-term the GDP per capita variable has a significant positive effect on CO2 emissions in Indonesia.

The t-statistic value of income inequality is -1.619765 < t-table value 1.70329 with a probability of 0.8248 more than alpha 5% (0.05), so in the long-term, the variable income inequality has a negative and insignificant effect on CO2 emissions in Indonesia.

The t-statistic value of the population is 8.450317 > the t-table value is 1.70329 with a probability of 0.0000 less than alpha 5% (0.05), then in the long-term the variable population has a significant positive effect on CO2 emissions in Indonesia.

F-Test

Short-term

Table 14 Short Term f-Test Result

f-table	f-statistics	Prob.	Information
2.96	9.479298	0.000073	significant

The results of the f-test calculation show that f-statistic is 9.479298 > f-table 2.96 with a probability of 0.000073 less than the alpha value of 5% (0.05), so that it can be concluded that the variables GDP per capita, income inequality, population, and ECT are together significantly influenced CO2 emission variable`s in Indonesia in the short term.

Long-term

Tabel 15 Long Term f-Test Result

f-table	f-statistics	Prob.	Information
2.96	544.8930	0.000000	significant

The results of f-test calculating show that the f-statistic is 544.8930 > f-table 2.96 with a probability of 0.000000 less than the alpha value of 5% (0.05), so that it can be concluded that the variable GDP per capita, income inequality, and total population together have a significant effect on CO2 emission variables in Indonesia in the long run.

Determination Coefficient Test (R2)

Regression results in the short-term obtained an R2 value of 0.593224 or 59.3224%. That is, GDP per capita, income inequality, and population together can explain 59.3224% of CO2 emissions. While the remaining 40.6776% is explained by other variables outside the research model. The long-term regression results obtained an R2 value of 0.983160 or 98.3169%. That is, GDP per capita, income inequality, and population together can explain 98.3169% of CO2 emissions. While the remaining 1.6831% is explained by other variables outside the research model.

Environmental Kuznet Curve (EKC) Hypothesis in Indonesia

Based on the estimation results, both in the short and long term have a coefficient sign that is by following per under the EKC hypothesis, namely positive on β1 and negative on β2. However, GDP per capita squared is not significant so the EKC hypothesis is not proven. The results of this study are in accordance with research conducted by Ibrahiem (2016) for a case study in Egypt. The results of this study indicate that the EKC hypothesis does not apply in Egypt both in the short and long term. This research is also in accordance with the results of research from Azwar (2019) that the EKC hypothesis does not apply in Indonesia.

SINOMICS JOURNAL
International Journal of Social Science, Education, Communication and Economics
ISSN (e): 2829-7350 | ISSN(p): 2963-9441

It has not been proven that the EKC hypothesis in Indonesia in the 1990-2021 period is rational. This is because CO2 emissions are a form of global pollution that takes a long time to increase or decrease (Kurniarahma et al., 2018). This is in line with the EKC formation phase where Indonesia is categorized as a developing country (Susanti, 2018). The EKC theory explains that developing countries in the early stages of development still prioritize economic development by increasing their production and income.

The Effect of GDP Per Capita on CO2 Emissions in Indonesia

Based on the estimation results, it shows that GDP per capita has a positive and significant effect on CO2 emissions in Indonesia both in the short term and in the long term. These results are in accordance with research from Fattah et al. (2021) and Putri et al. (2022) which concludes that GDP per capita has a positive and significant influence on Indonesia in the short-term and long-term. An increase in GDP per capita can increase energy consumption and industrial production which contribute to an increase in CO2 emissions. Increased production and consumption of energy will increase the use of fossil fuels, which are the main source of CO2 emissions.

The Effect of Income Inequality on CO2 Emissions in Indonesia

The estimation results show that income inequality has no significant positive effect on CO2 emissions in the short-term, and no significant negative effect in the long-term. The results of this study are in accordance with research conducted by Ghazouani & Beldi (2022) which states that there is no significant effect between income inequality and CO2 emissions in seven Asian countries.

The Effect of Population on CO2 Emissions in Indonesia

The results of this study are in accordance with research conducted by Trisiya (2022) which resulted in the conclusion that population has a positive and significant influence on CO2 emissions in Indonesia in the long-term. This means that the higher the population, the CO2 emissions also increase. Meanwhile, in the short-term there is no significant relationship between population and CO2 emissions in Indonesia, the population shows a negative result on CO2 emissions. An increase in population in general will increase the need for energy, transportation, and consumption of fossil fuels, which can lead to an increase in CO2 emissions. However, in the short-term, the effect of an increase in population on CO2 emissions can be negative because of the effect of an economic down turn which has an impact on reducing economic activity, transportation, and energy consumption.

CONCLUSION

Based on the results of the research, it can be concluded as follows:

1. The Environmental Kuznet Curve hypothesis does not apply in Indonesia either in the short term or in the long term.

2. The variable GDP per capita has a positive and significant effect on CO2 emissions in Indonesia both in the short term and in the long term.
3. Income inequality variable has no significant positive effect in the short term and no significant negative long-term effect on CO2 emissions in Indonesia.
4. The population variable has no significant negative effect in the short term and has a significant positive effect in the long term on CO2 emissions in Indonesia
5. GDP per capita variables, income inequality, and population have a significant effect on CO2 emissions in Indonesia.

SUGGESTIONS

Suggestions that can be conveyed in this research are:

1. The government should strive to achieve net zero emissions by creating environmentally friendly energy innovations or new renewable energy transitions.
2. The government should be able to provide job opportunities and improve the quality of human resources to reduce income inequality.
3. The government should be able to optimize the family planning program so that it can reduce the population.

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