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The Effect of GDP Per Capita, Population, and Income Inequality on CO_2 Emissions in Indonesia

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ABSTRACT

This study aims to see the effect of GDP per capita, income inequality, and population on CO_2 emissions in Indonesia from 1990 to 2021. This research uses a descriptive quantitative method. The data used is secondary data, in the form of annual data for 32 years. The analytical method used is the error correction model (ECM) to see the short- and long-term effects between the independent and dependent variables. The results of this study indicate that GDP per capita has a positive and significant effect on Indonesia, both in the short term and in the long term. The income inequality variable has a positive and insignificant effect on CO_2 emissions in Indonesia in the short term. Meanwhile, in the long term, income inequality has a negative and insignificant effect on CO_2 emissions in Indonesia. The population variable has an insignificant negative effect on CO_2 emissions in Indonesia in the short term. However, in the long term, the population significantly affects CO_2 emissions in Indonesia.

Keywords: CO_2, GDP, Income Inequality, Population
JEL Classifications: D63, O10, P23

1. INTRODUCTION

Environmental degradation is a topic that is often raised because it is a serious problem at the world level. The most serious impact due to environmental degradation is global warming. Global warming is caused by the rise of Greenhouse Gases (GHG). Currently, Indonesia continues to experience an increase in GHG emissions from year to year. Based on data from the Ministry of Environment and Forestry (2021) shows that the energy sector is the largest contributor to GHG emissions in Indonesia, which is 34%, followed by the waste sector (7%), agriculture (6%), and IPPU (3%). This shows that the energy sector has a dominant contribution to national GHG emissions. Based on IPCC GL 2006 guidelines, gases from the energy sector consist of CO_2, CH_4, and N_2O. Ministry of Environment and Forestry(2021) stated that CO_2 emissions have the largest contribution to total national GHG emissions at 93%, followed by CH_4 (6%), and NO_2 (1%).

Environmental degradation is defined as a decrease in environmental quality caused by natural factors and human factors. The main factor that causes environmental degradation is the human factor. Human factors that cause environmental degradation include industrial activities, land use change, the use of fossil energy, and others. Environmental degradation is driven by a country's need to promote economic growth and development and meet human needs (Reswita et al., 2021).

Economic growth and development become an analytical agenda that has a role to improve welfare (Firmansyah, 2021). Economic growth indicates an increase in the country's productivity to produce goods and services (Finanda and Toto, 2022). The main indicator characterizing economic growth is Gross Domestic Product (Grishin et al., 2019). Currently, Indonesia continues to experience a positive trend of economic growth, growing by 5.03% in 2016, 5.17% in 2017, and 5.17% in 2018 (Central Bureau of Statistics, 2022). In an effort to increase economic growth, it is necessary to carry out economic activities and energy consumption. According to Nikensari et al. (2019) economic activities that require energy, for example industry contributes 60% to CO_2 emissions. This is also in line with the contribution of the industrial sector which reaches 19.8% of national GDP (Ministry of Industry, 2022), meaning that an increase in GDP causes environmental degradation in the form of CO_2 emissions. The biggest challenge for developing countries is being able to maintain economic growth, while maintaining environmental quality (Ahmad et al., 2021; Sadiq et al., 2022; Fajriani et al., 2023).

GDP will describe the economic performance in a country (Syari et al., 2017). Increasing economic growth without improving the structure of development causes problems of inequality in society. Income inequality occurs due to the gap in income distribution among community groups. According to Gulzar et al. (2020) Income inequality is a factor causing environmental pollution in developing countries. Income inequality causes the government's internal attention to be focused on economic growth policies only, without regard to environmental aspects (Magnani, 2000). Economic growth efforts to reduce income inequality lead to increased resource use and energy consumption. This is a factor causing the increase in CO_2 emissions.

As an effort to increase GDP, it takes people or humans as development actors. The population becomes an economic actor, both as a producer and a consumer. Currently, the population of Indonesia continues to increase from year to year. According to Mahendra et al. (2022) An ever-increasing population will be followed by an increase in demand for goods and services which in turn increases the use of natural resources. The increase in demand for goods and services affects the increase in industrial activity. In addition, the growing population also causes an increase in the use of energy such as fossil fuels which results in environmental degradation in the form of CO_2 emissions. While CO_2 emissions are a serious problem that has a direct impact on the environment (Putri et al., 2022b).

The focus of this study is the rapid increase in GDP every year, income inequality, and increasing population that causes CO_2 emissions in Indonesia. This research combines economic, environmental, and social aspects contained in the concept of sustainable development. This study looks at the effect of GDP per capita, population, and income inequality on CO_2 emissions in Indonesia both in the short and long term.

2. LITERATURE REVIEW

Indonesia continues to experience rapid economic growth. The indicator that characterizes economic growth is Gross Domestic Product (GDP). GDP is the main parameter to determine economic conditions in two regions in a certain period of time because it calculates the added value and value of final goods and services produced (Sharia et al., 2017). Indirectly, efforts to increase GDP encourage an increase in production and industrial activity. Economic growth is a parameter that determines the success of economic development, but on the other hand can cause environmental degradation in the form of CO_2 emissions. According to Drews and Bergh (2017) exist *Trade Off* between economic growth and environmental preservation.

The increasing GDP figure does not guarantee that Indonesia is free from social problems in the form of income inequality. In fact, the richest 10% of people in Indonesia control 75.7% of national wealth and the richest 1% of people in Indonesia control 49.3% of national wealth (Mawardi, 2018). The data proves that Indonesia still experiences income inequality, where inequality can affect CO_2 emissions.

According to Adam Smith's theory, one of the most important components of economic growth is population. The increase in population in Indonesia is also accompanied by an increase in economic growth. However, the increase in population causes an increase in the use of natural resources that cause pollution. The increasing population also has an impact on increasing energy use which causes CO_2 emissions. Based on this explanation, the researcher determines the following problem formulation: (a) How did GDP per capita affect CO_2 emissions in Indonesia in 1990-2021?; (b) How does population affect CO_2 emissions in Indonesia in 1990-2021? And (c) How did income inequality affect CO_2 emissions in Indonesia in 1990-2021?

3. RESEARCH METHODS

The research method used is a quantitative method with a descriptive approach. Quantitative methods are research methods in the form of numbers measured by statistical tests to provide conclusions. The descriptive approach used serves to describe the results of research by presenting, analyzing, and interpreting them. The scope of this research is Indonesia. The data used is annual data or *time series* for 32 years starting from 1990 to 2021. Research data obtained from the World *Bank* and *Our World in Data*.

This study consisted of 3 independent variables and 1 dependent variable. The independent variables used are GDP per capita in units of US $, variables in population with units of thousands of people, and variables of income inequality measured using the Gini ratio. The dependent variable is CO_2 emissions in tons. CO_2 emissions taken into account in this study are only emissions derived from fossil and industrial energy.

Time series data requires stationary data. So before estimating data, it is necessary to perform a stationary test. Data is said to be stationary if the data does not have drastic changes. The first data analysis carried out was a stationary test. The stationarity test conducted in this study used the *Dickey-Fuller Augmented method* by comparing the t-statistical ADF with MacKinnon's critical value. If the ADF value of t-statistics is greater than the critical value of MacKinnon 5%, then the data is stationary. If the stationary test data shows results that are not yet stationary, then an integration test is carried out. Integration tests are performed to see to what degree the data will be stationary. Furthermore, the cointegration test uses the *Engel Granger* (EG) test. *The Engel Granger test can determine the cointegration of stationarity in its residuals.*

Data estimation in this study uses *error correction model* (ECM). ECM estimation aims to determine whether there are short-term and long-term influences on the variables tested. Equation

The ECM in this study is as follows:

$$\Delta CO2 = \alpha 0 + \alpha 1 \Delta PDB_t + \alpha 2 \Delta GR_t + \alpha 3 \Delta P_t + \varepsilon_t \quad (1)$$

For the regression equation in the long run it is written as follows:

$$CO2 = \beta 0 + \beta 1 PDB_t + \beta 2 GR_t + \beta 3 P_t + \varepsilon_t \quad (2)$$

Information:

CO_2	: CO_2 emissions
.PDB	: GDP per Capita
GR	: Income Inequality (Gini ratio)
P	: Population
α0 and β0	: Constant
α1, α2, α3 and β1, β2, β3	: Regression Coefficient
ε	: *Error term* (Redisual)

The \ method *is characterized by the presence of an element of* error correction term (ECT). ECT is a residual that appears in the ECM model. If the value of the ECT coefficient < 1 and significant at 5%, then the specification model used is valid.

After obtaining the research model, the next stage is to test classical assumptions. The classical assumption tests used in this study are normality tests, autocorrelation tests, heteroscedasticity tests, and multicollinearity tests. The normality test uses the *Jarque-Bera* test, if the JB value > α 5%, then the residual is normally distributed. Aucoration test using Durbin-Watson test, if DW value is between −2 and +2, then there is no autocorrelation problem. Test heteroscedasticity using the Breusch-Pagan-Godfrey test, if the value of Prob. Chi-square is more than 0.05, so there is no heteroscedasticity problem. Multicollinearity test using VIF test, if the test result is below 10, then there is no multicollinearity problem.

4. RESULTS, ANALYSIS, AND DISCUSSION

Time series data requires stationary data. Stasisonarity test using the Dickey-Fuller Augmented method is shown in the Table 1:

Based on Table 1, it shows that the ADF test value on all variables is smaller than the MacKinnon critical value and the probability value is more than α 5%, so that all variables are not stationary at the level level. Furthermore, a differentiation test is carried out to find out at the degree of integration to how much the data will be stationary. Here is the integration test in this study:

Based on the results of the integration test (Table 2), it shows that the ADF test value on all variables is greater than the MacKinnon critical value and the Probability value is <α 5%, so that all variables are stationary at the level of *first differrence*. Because all variables are stationary at the first difference level, the next stage is to conduct a cointegration test in order to be able to perform ECM estimation. The cointegration test is shown in the following Table 3.

Based on the results of the cointegration test, it shows that the probability value is 0.0012 < α 5% and the ADF test value is more than the critical value. Thus, the equation tested has a long-term equilibrium relationship. So that the estimation model can be interpreted further.

This study uses the ECM Domowitz El Badawi estimation model to determine the short-term and long-term effects of GDP per capita, income inequality, and population to CO_2 emissions. The results of regression in the short term are shown in the Table 4.

Based on the results of estimates in the short term, the regression equation is obtained as follows:

$$CO2 = 62045241 + 40630.62 PDB + 698885.5 GR - 16.79596 P - 0.832239$$

The equation shows that the value of the constant is 62045241, meaning that if the value of all independent variables is zero, then the value of CO_2 emissions is 62045241 tons. The value of the coefficient in the variable GDP per capita is 40630.62, meaning that when GDP per capita increases by 1 US$, CO_2 emissions will increase by 40630.62 tons (cateris paribus). The coefficient in the income inequality variable is 698885.5, meaning that when inequality increases by 1%, CO_2 emissions will increase by 698885.5 tons (cateris paribus). The coefficient on the variable population is −16.79596, meaning that when the population increases by 1 million, CO_2 emissions will decrease by 16.79596 tons (cateris paribus). Meanwhile, the value of the coefficient in the ECT variable is −0.832239, because it has a negative sign (ECT < 1) and is significant at α 5%, the model specification used is valid. The R-square value has a coefficient of 0.593224, meaning that GDP per capita, income inequality, and population together can explain 59.3224% of CO_2 emissions. While the rest is explained by other variables outside the research model. Table 4 also shows that based on the t-test the variable GDP per capita has a significant positive effect (Prob < 0.05), the income inequality variable has a positive effect is not significant (Prob > 0.05), and

Table 1: Stasionecity test at level level

Variable	ADF test scores	McKinnon critical values			Prob.	Information
		1%	5%	10%		
CO_2	−0.492203	−3.661661	−2.960411	−2.619160	0.8797	Non-stationary
.PDB	0.248447	−3.661661	−2.960411	−2.619160	0.9714	Non-stationary
GR	−0.981690	−3.661661	−2.960411	−2.619160	0.7473	Non-stationary
P	−1.889931	−3.737853	−2.991878	−2.635542	0.3311	Non-stationary

Table 2: Integration test on first difference

Variable	ADF test scores	McKinnon critical values			Prob.	Information
		1%	5%	10%		
CO_2	−5.405547	−3.679322	−2.967767	−2.622989	0.0001	Stationary
.PDB	−4.314652	−3.670170	−2.963972	−2.621007	0.0020	Stationary
GR	−4.396564	−3.670170	−2.963972	−2.621007	0.0016	Stationary
P	−3.036626	−3.699871	−2.976263	−2.627420	0.0441	Stationary

Table 3: Cointegration test

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

Table 4: Short−Term estimation results

Variable	Coefficient	SE	t−Statistic	Prob.
C	62045241	77047907	0.805281	0.4280
D (GDP)	40630.62	17211.78	2.360629	0.0260
D (INEQUALITY)	698885.5	3124697.	0.223665	0.8248
D (RESIDENT)	−16.79596	25.13333	−0.668274	0.5098
ECT(−1)	−0.832239	0.195686	−4.252934	0.0002
R-squared	0.593224			
Adjusted R-squared	0.530643			
F-statistic	9.479298			
Prob (F-statistic)	0.000073			

the population variable has a negative effect is not significant (Prob > 0.05) on CO_2 emissions in Indonesia in the short term. Meanwhile, simultaneously (test f) all variables together have a significant effect on C2 emissions in Indonesia (Prob f-statistics < 0.05).

Next is the classical assumption test which aims to find out whether the estimated results violate classical assumptions or not. The first classical assumption test is the normality test. Based on the results of the normality test, a Jarque-Bera value of 0.900505 > 0.05 was obtained, so that the data can be concluded normally distributed. Then based on the results of the autocorrelation test showed that the Durbin-Watson value in this study was 1.920450, it can be concluded that there is no autocorrelation problem in the regression model. Based on the results of the heteroscedasticity test shows that the value of Prob. ChiSquare is 0.4816 > 0.05, so it can be concluded that there is no heteroscedasticity problem. Based on the results of the multicollinearity test, a VIF value of <10 is obtained on each variable, it can be concluded that there is no problem heteroscedasticity in regression models. The long-term estimation model is shown in the Table 5.

Based on the results of the estimation in the long term, the regression equation is obtained as follows:

$$CO2 = -3.19 + 50154.20PDB - 4716203GR + 3.344576P$$

The regression equation shows that the constant value is −3.19, meaning that in the long run if all independent variables are zero, the CO_2 emission value is −3.19 tons. The value of the coefficient in the variable GDP per capita is 50154.20, meaning that if GDP per capita increases by 1 US $ then CO_2 emissions

Table 5: Long-term estimation results

Variable	Coefficient	SE	t-Statistic	Prob.
C	−3.19E+08	1.38E+08	−2.319187	0.0279
.PDB	50154.20	12143.09	4.130268	0.0003
INEQUALITY	−4716203.	2911658.	−1.619765	0.1165
JUMLAH_ PENDUDUK	3.344576	0.395793	8.450317	0.0000
R-squared	0.983160			
Adjusted R-squared	0.981355			
F-statistic	544.8930			
Prob (F-statistic)	0.000000			

will increase by 50154.20 tons (cateris paribus). The value of the variable coefficient of income inequality is −4716203, meaning that if income inequality increases by 1%, CO_2 emissions will decrease by 4716203 tons (cateris paribus). The value of the coefficient on the population variable is 3.344576, meaning that if the population increases by 1 million people, CO_2 emissions will increase by 3.344576 tons (cateris paribus). Meanwhile, the R-squared coefficient of 0.983160 means that GDP per capita, income inequality, and population together can explain 98.3160% of CO_2 emissions. While the rest is explained by other variables outside the research model. Table 4 shows that based on the t-test the variable GDP per capita has a significant positive effect (Prob < 0.05), the income inequality variable has a negative effect is not significant (Prob > 0.05), and the population variable has a significant positive effect (Prob < 0.05) on CO_2 emissions in Indonesia in the long run. Meanwhile, based on simultaneous tests (test f) shows that all independent variables have a significant effect on CO_2 emissions in Indonesia in the long term. This can be seen from the statistical probability value f

amounting to 0.000000 < 0.05.

4.1. The Effect of GDP per Capita on CO_2 Emissions in Indonesia

The variable GDP per capita has a positive and significant influence on CO_2 emissions in Indonesia in 1990-2021, both in the long and short term. The results of this test are the same as the research conducted by Daughter et al. (2022) and Fattah et al. (2021). The research provides results that in the short and long-term GDP per capita has a positive effect on CO_2 emissions in Indonesia. Efforts to increase GDP require economic activities such as consumption and production. The ever-increasing GDP shows that people's purchasing power is getting bigger. The higher the consumption, the higher the production in industries that require the use of fossil energy. This is a trigger for CO_2 emissions. So it can be concluded that the increase in GDP per capita in Indonesia causes an increase in CO_2 emissions through increased consumption of fossil energy and industrial activities.

4.2. The Effect of Income Inequality on CO_2 Emissions in Indonesia

The estimation results in this study show that income inequality variables have a positive and insignificant influence on CO_2 emissions in Indonesia in the short term. Meanwhile, in the long run, income inequality has a negative insignificant influence on CO_2 emissions in Indonesia. The results of this study are the same as the research conducted by Ghazouani and Beldi (2022) and Ali (2022). The study showed that there was no significant effect between income inequality and CO_2 emissions. The mechanism of the effect of income inequality on CO_2 emissions in the short term can be explained through efforts to increase economic growth. Income inequality drives up GDP through increased production that requires energy use. This is the main trigger for CO_2 emissions. This reason is also supported by the focus of development that is only concerned with economic growth rather than environmental sustainability. However, in the long run the link between income inequality and CO_2 emissions becomes negative. This is due to efforts to reduce income inequality and the development of clean technology innovations. So in the long run the relationship between income inequality and CO_2 emissions becomes negative.

4.3. The Effect of Population on CO_2 Emissions in Indonesia

The estimation results in this study show that population has a negative insignificant influence on CO_2 emissions in the short term. While in the long run the effect becomes positive and significant. This research is the same as the research conducted by Trisiya (2022), which results that the effect of population on CO_2 emissions in Indonesia is negative not significant in the short term and positive significant in the long term. The increasing population has led to an increase in people's need for energy and increased production, causing an increase in CO_2 emissions. However, in the short term the influence of population on CO_2 emissions becomes negative due to the effect of decreasing economic growth which reduces the use of fossil energy and reduced industrial activities.

5. CONCLUSIONS, IMPLICATIONS, SUGGESTIONS AND RECOMMENDATIONS

The variable GDP per capita has a positive and significant influence on CO_2 emissions in Indonesia in 1990-2021, both in the long and short term. So it can be concluded that the increase in GDP per capita in Indonesia causes an increase in CO_2 emissions through increased consumption of fossil energy and industrial activities.

The estimation results in this study show that income inequality variables have a positive and insignificant influence on CO_2 emissions in Indonesia in the short term. Meanwhile, in the long run, income inequality has a negative insignificant influence on CO_2 emissions in Indonesia. Income inequality drives up GDP through increased production that requires energy use. This is the main trigger for CO_2 emissions.

The estimation results in this study show that population has a negative insignificant influence on CO_2 emissions in the short term. While in the long run the effect becomes positive and significant. The increasing population has led to an increase in people's need for energy and increased production, causing an increase in CO_2 emissions. However, in the short term the influence of population on CO_2 emissions becomes negative due to the effect of decreasing economic growth which reduces the use of fossil energy and reduced industrial activities.

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