ERROR CORRECTION MODEL: FACTORS AFFECTING CARBON EMISSIONS IN SUPPORTING SUSTAINABLE DEVELOPMENT IN INDONESIA

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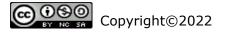e-mail: fardinep16@gmail.com

ABSTRACT

This study is a study that aims to determine the effect of population, economic growth, and consumption of renewable energy on CO_2 emissions in Indonesia. The type of data used in this study is secondary data and is time-series data from 1990-to 2019. The method of analysis in this study is the Error Correction Model (ECM) which aims to determine the existence of short-term and long-term relationships between the analyzed variables. Based on the results of data analysis conducted in this study, it can be concluded that in the short term population and consumption of renewable energy have no effect on CO_2 emissions in Indonesia, while economic growth has a positive effect on CO_2 emissions in Indonesia. In the long term, the results obtained are that population and economic growth have a positive effect on CO_2 emissions in Indonesia, while consumption of renewable energy has no effect on CO_2 emissions in Indonesia.

Keywords: *Population, Economic Growth, Renewable Energy Consumption, CO_2 Emissions*

INTRODUCTION

Economic development should still pay attention to environmental aspects, namely implementing sustainable development (Febriana et al., 2019). The concept of sustainable development (Sustainable Development Goals) is a development paradigm concept that is oriented towards environmental balance (Rosana, 2018). Economic development that ignores environmental aspects certainly has a negative impact on natural sustainability where inputs from production factors mostly come from nature. In addition, one of the indicators used to see the achievement of the concept of sustainable development is to measure the level of CO2 emissions.

CO_2 emissions are compounds originating from power plants, transportation, commercial residential buildings that use Air Conditioners (cooling or heating systems), and industrial production (Schreurs & Balanowski, 2017). CO_2 emissions are also one of the greenhouse gases (GHG). Indonesia is the fourth-largest greenhouse gas (GHG) emitter in the world. Based on data from the Carbon Brief (2021) through data collected by the Potsdam Institute for Climate Impact

Research (PIK), shows that the level of CO_2 emissions in Indonesia has reached 2.2 billion tons of CO_2 equivalent ($GtCO_2e$) in 2015. The phenomenon of CO_2 emissions in Indonesia tends to experience an increase from 1990 of 150.2859 $MtCO_2$ to 2019 of 617.5126 $MtCO_2$. Where the increase in CO_2 emissions can cause global warming.

Global warming is currently a big problem that is being faced by the world. This is if global warming continues to increase, it will have a negative impact on human survival. One of the effects of global warming is climate change. Based on data from Climate Transparency (2018), Indonesia's risk due to the impact of climate change will adversely affect the availability of clean water, and increase cases of nutrition and diarrheal diseases in the health sector. Meanwhile, in the infrastructure sector, the impact of climate change will affect the availability of renewable energy, namely the proportion of coastlines affected by sea-level rise, thereby reducing the capacity of hydropower generation. In addition, climate change if it occurs in an extreme manner can affect agricultural productivity. This is due to a shift in the seasons that can cause crop failure for farmers. If this condition continues, it can threaten food security and economic stability.

Aspects of the economy that are driving factors for increasing CO_2 emissions are population, economic growth, and the use of technology. The increasing number of people makes it possible to encourage high CO_2 emissions. This is because humans are the cause of environmental damage (environmental degradation). Where human activities that do not pay attention to the environment will have a negative impact on the ecological balance. Economic activities have negative externalities on the environment. This also affects economic growth which increases but has an impact on environmental degradation. In addition, of course, the use of technology also plays an important role in reducing the increase in CO_2 emissions. The increase in CO_2 emissions will continue to occur if the use of energy that is not environmentally friendly dominates, such as the consumption of petroleum, the use of coal for power plants, vehicle fumes, factory machinery, and other environmentally unfriendly technologies.

The relationship between these three problems can be explained in a model known as the IPAT (Impact-Population-Affluence-Technology) model. The model can explain the economic relationship to environmental degradation. So that this can provide a clear picture of the problems that exist in the environment and their relationship to economic activity. In addition, the application of the IPAT model can also be used to measure all kinds of environmental impacts.

Several previous studies related to this research were carried out (Anjani, 2013; Umniati, 2015; Chontanawat, 2018; Mansoor & Sultana, 2018; Ihsan, 2019). The similarity in this study is in the application of the IPAT model which is the theoretical basis to explain how the relationship between economic relations and environmental degradation is related. So that the variables studied also have similarities as indicators in the IPAT model (Impact is measured using CO_2 emissions, Population is measured using population and urbanization, Affluence is

measured using GDP and economic growth, while Technology is measured using energy consumption and energy intensity). Meanwhile, the difference in this study lies in the observation area in Indonesia and the Error Correction Model (ECM) analysis model used, as well as energy consumption observations on technology focusing on renewable energy consumption.

This research is expected to be able to answer the problem of the impact of the economy on environmental problems in Indonesia through an analysis of the driving factors for CO_2 emissions that support sustainable development. The driving factors for CO_2 emissions in this study are economic variables, namely population, economic growth, and consumption of renewable energy which were analyzed using the application of the IPAT model. The IPAT model is carried out to see the effect of population, economic growth, and consumption of renewable energy on CO_2 emissions. So based on the problems above, this study aims to examine the analysis of the factors that influence carbon emissions in supporting sustainable development in Indonesia.

MATERIALS AND METHODS

This research is quantitative research with an associative approach. The variables used in this study are population, economic growth, and consumption of renewable energy as independent variables and CO2 emissions as the determining variable. This study uses secondary data in the form of time series data with a time series of 1990-2019. The data used in this study were obtained from various sources, namely CO2 emissions from the Global Carbon Atlas, population and economic growth from the World Development Indicator (World Bank), and renewable energy consumption from Our World in Data and BP Statistical Review of World Energy. The data analysis technique used in this study is a dynamic method in the form of Error Correction Mechanism (ECM) analysis. This method is used to view and analyze research problems, namely how the influence of variables on variables both in the short and long term. The regression model used in this study is as follows:

Long-term regression model
$$ECO = \beta_0 + \beta_1 P_t + \beta_2 PE_t + \beta_3 KTE_t + e_{1t} \tag{1}$$

Short-term regression model
$$D(ECO) = \beta_4 + \beta_5 D(P_t) + \beta_6 D(PE_t) + \beta_7 D(KTE_t) + e_{2t} \tag{2}$$

Information: ECO: CO_2 emissions; P: Population; PE: Economic Growth; KTE: Renewable Energy Consumption; $\beta_1, \dots, \beta_7$: Coefficient of Determination; β_0: Constant; e_{1t}, e_{2t}: Residual Value (Previous Period).

RESULT AND DISCUSSION

1. Stationarity and Cointegration Test

Stationary testing in this study used the Dickey-Fuller test method. The unit root test in ECM testing aims to analyze that the time series data is stationary, which is an important requirement in managing time-series data.

Table 1. Unit root stationarity test results

Research variable	T-Statistic	Probability	Description
CO_2 Emissions	-6.470599	0.0000	Stationary
Population	-2.054942	0.0404	Stationary
Economic Growth	-4.792307	0.0000	Stationary
Renewable Energy Consumption	-10.75969	0.0000	Stationary

Source: Output secondary data after processing Eviews 9.

Based on the results of unit root testing using the Dickey-Fuller method, it is known that all research data is stationary at the first different level where the t-statistic value is greater than the McKinnon table value at a confidence level of 1%, 5%, or 10%. And the critical probability value is less than 0.05 (<0.05). So that the cointegration test can then be carried out.

After the stationary test is carried out, the next step is the cointegration test. The Cointegration test aims to determine whether there is cointegration in variable data that shows a short-term and long-term relationship between variables. The cointegration test method used in this study is the Johansen Cointegration Test method.

Table 2. Cointegration test results

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.783882	98.41814	55.24578	0.0000
At most 1 *	0.706327	55.52411	35.01090	0.0001
At most 2 *	0.445090	21.21607	18.39771	0.0197
At most 3 *	0.155295	4.725484	3.841466	0.0297

Trace test indicates 4 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Source: Output secondary data after processing Eviews 9.

Based on Table 2, the cointegration test shows that the data processing carried out has cointegration which is seen from the statistical trace value which is smaller than the critical value. The results of the statistical trace value test and the critical value show that there is cointegration at a significant level of = 5%. It can be concluded that the data has a long-term relationship. So that it can be continued with further testing with data analysis of the ECM (Error Correction Model) model.

2. ECM Estimation Results

The analysis of the ECM model is an approach taken to determine the short-term and long-term relationship in the research equation model. This test can be carried out on the condition that the research variables analyzed have met the cointegration test. The results of the estimation of ECM both in the short and long term in this study are as follows:

Table 3. Estimation results of ECM

Variable	Long-term			Short-term		
	β	t- hit	Sign	B	t- hit	Sign
Population	4.38E-06	8.632425	0.0000	-4.81E-06	-0.094054	0.9259
Economic Growth	4.551771	4.337270	0.0002	4.489221	2.793801	0.0103
Square Economic Growth	0.242016	1.473967	0.1530	0.154735	1.046150	0.3064
Renewable Energy Consumption	130.2414	0.951412	0.3505	-116.6682	-0.761219	0.4543
Intercept	-691.8480	-7.839142	0.0000	32.78945	0.212267	0.8338
R-square			0.947097			0.504934
Adjusted R-square			0.938633			0.397311
F-statistic			111.8908			4.691698
Pro (F-statistic)			0.000000			0.004244

Source: Output secondary data after processing Eviews 9.

Based on the results of the F test, it is concluded that population, economic growth, and consumption of renewable energy simultaneously have a significant effect on CO_2 emissions in Indonesia both in the short and long term. So it can be interpreted that the IPAT model can explain changes in CO_2 emissions in Indonesia. When viewed from the value of the coefficient of determination in the regression, it shows that 94,7097% of the influence given by the independent variable on the dependent variable and 5,2903% is influenced by other variables in the long-term equation results. While the value of the coefficient of determination on the results of the short-term equation shows that 50,4934% of the influence is given by the independent variable to the dependent variable and 49,5066% is influenced by other variables. So it can be concluded that there are other independent variables outside the model that contribute to influencing the level of CO_2 emissions in Indonesia. This is because environmental issues are very complex studies that are not only influenced by economic variables. However, it is also influenced by other factors such as environmental policies, geography, and so on.

Effect of Population on CO_2 Emissions

Based on the short-term estimation results, it shows that the population has no effect on increasing CO_2 emissions in Indonesia. While the long-term estimation results show that the population in the long term has a positive effect on increasing CO_2 emissions in Indonesia, meaning that if the population increases by 1%, there

will be an increase in CO_2 emissions of 4.380722%. This is in line with research conducted by Chontanawat (2018) who conducted a study in ASEAN countries and found that population had a positive effect on CO_2 emissions. So that any increase in population in ASEAN countries can cause an increase in CO_2 emissions. Besides that, (Ayuningtyas, 2020) found the same fact in his research on the effect of population on CO_2 emissions in ASEAN. According to him, every increase in population can have a positive effect on increasing CO_2 emissions in ASEAN.

According to Malthus' theory, an increase in the population of a country will generally have an impact on increasing the need for food availability. The increasing rate of population will certainly affect the rate of demand for goods and services. So to overcome this gap, efforts to increase mass production in industrial activities continue to be increased. However, this will have a negative impact on the environment. Efforts to increase production that continue to exploit limited natural resources as a factor of production will actually cause negative externalities that it has a negative impact on environmental sustainability.

The contribution of Indonesia's population growth to the increase in CO_2 emissions is not without reason. Indonesia itself is a country with the fourth-largest population in the world. Based on World Bank data, in 2019 Indonesia's population reached 270 million. So to overcome this, it is necessary to make efforts to conserve the environment by involving the community. As stated by Dietz and Rosa Anjani (2013), argues that one of the determinants of the quality of the population is the level of education and awareness. This is because the level of education and awareness greatly affects a person's behavior in preserving the environment. Meanwhile, according to research Yao et al. (2020) explain that there is a link between the quality of human resources and environmental sustainability. According to him, the higher the quality of human capital will have an effect on decreasing CO_2 emissions in OECD countries. This is because higher education can encourage advanced human resources in preserving the environment.

Effect of Economic Growth on CO_2 Emissions

Based on the estimation results, economic growth has a positive and significant effect on CO_2 emissions in Indonesia, both in the short and long term. The regression results show that a 1% increase in economic growth in the short term can have an effect on an increase of 4.489221%. Meanwhile, in the long term, a 1% increase in economic growth will increase CO_2 emissions by 4.551771%. So that the positive influence between economic growth and CO_2 emissions can provide an illustration that economic activities in Indonesia still have a negative externalities impact on environmental sustainability. Regression results that show the coefficient value is positive are in line with the research conducted by Ayuningtyas (2020) that the positive value of the coefficient means that economic growth has an influence on increasing CO_2 emissions. GDP per capita is used as an indicator in measuring economic growth. The results of his research show that a 1% increase in economic growth will contribute to an increase in CO_2

emissions in ASEAN. So to overcome this, clear government regulations are needed to suppress the rate of increase in CO_2 emissions in each country.

This study also aims to reveal the existence of the Environmental Kuznets Curve (EKC) hypothesis in Indonesia. EKC theory explains the relationship between economic growth that can affect the environmental quality of a country. This hypothesis assumes that the early stages of economic growth can result in environmental damage as per capita income increases. This is because, in the early stages of economic growth, the economy is being transformed from a rural economy to an urban one, which focuses more on industrialization activities that ignore environmental sustainability. However, when the increase in per capita income has passed the income turning point, which is marked by a service economy basis (post-industrial economy). This condition causes economic activity to no longer cause environmental damage. This is because the economic structure has shifted from heavy industry to a service-based economy, thus assuming increased economic growth can reduce environmental damage.

The facts show that the EKC hypothesis is not proven to occur in Indonesia. This can be seen from the coefficient value in the economic growth regression which is positive, is 0.242016, and is significant to the probability value. While the value of the squared economic growth regression coefficient is positive and not significant. So that it illustrates that an increase in economic growth will cause environmental damage such as the condition of the EKC hypothesis in the early stages. This condition is due to the fact that Indonesia's economic sector in 2018 was still dominated by the agricultural, trade, and processing industries. Based on the data Badan Pusat Statistik (2019) the contribution of the economic sector to Indonesia's economic growth in 2018, shows that the manufacturing industry dominates contributing to GDP by 19.86%, while the free trade and retail sectors; Car and motorcycle repairs contributed 13.02%, and the agriculture, forestry and fishery sectors contributed 12.81%. In addition, other sectors that also make a large contribution to GDP are the construction sector with 10.53%, and the rest is influenced by other sectors which are not too high. So it can be concluded that the condition of the Indonesian economy has not yet reached a post-industrial economy (service economy) but is undergoing a transformation from a pre-industrial economy (an economy that relies on agriculture) to an industrial economy where economic activity at this stage still causes a lot of environmental damage.

Effect of Renewable Energy Consumption on CO_2 Emissions

The results of the analysis of this study indicate that the consumption of renewable energy has no effect on CO_2 emissions in Indonesia, both in the short and long term. This is not in line with the researchers' expectations, that the increasing consumption of renewable energy will have an effect on reducing the level of CO_2 emissions in Indonesia.

According to research conducted by Dong et al. (2017) pointed out that the consumption of renewable energy has a negative effect on CO_2 emissions in BRICS countries. So that a 1% increase in renewable energy consumption can reduce CO_2 emissions. Even so, the application of renewable energy still faces some technical obstacles. Low energy efficiency and lack of infrastructure are obstacles that are being faced in the rapid development of industrial renewable energy in BRICS countries.

The use of energy has become an important part of everyday human life and is even an important pillar of economic development. Energy seen from its source consists of two, namely fossil energy and non-fossil energy or commonly known as renewable energy. Fossil energy can be regarded as an energy that is not environmentally friendly so its use too much can cause problems in environmental damage. So to overcome this, renewable energy can be a solution in the use of energy that is environmentally friendly and sourced from clean energy, such as water, hydrothermal, hydropower, geothermal, wind, solar, garbage, biomass, biofuel, to ocean waves. So there is no need to worry about high energy consumption because the increasing consumption of renewable energy will not cause damage to the environment. However, the reality is that the transformation of fossil energy into renewable energy is not as easy as imagined, it requires government policy support and the role of industry players to transform the use of technology and energy that is environmentally friendly. In addition, the application of renewable energy still has problems because its application requires a lot of money.

CONCLUSIONS

Based on the results of the research that has been described, it is concluded that in the short term population and consumption of renewable energy have no effect on CO_2 emissions in Indonesia, while economic growth has a positive effect on CO_2 emissions in Indonesia. In the long term, the results obtained are that population and economic growth have a positive effect on CO_2 emissions in Indonesia, while consumption of renewable energy has no effect on CO_2 emissions in Indonesia.

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