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Analysis Of The Influence Of Energy Consumption, Carbon Emissions, And Greenhouse Gas Emissions Reduction On Economic Growth In Indonesia

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Abstract

This study aims to determine the effect of energy consumption, carbon emissions, greenhouse gas emission reduction on economic growth in Indonesia. The results obtained from this study are in the short term, the energy consumption variable in the current year has a positive effect on economic growth in Indonesia, while the energy consumption variable (in the previous 1 year, 2 years earlier, and 3 years earlier) has a negative effect on economic growth in Indonesia. Then the carbon emission variable in the current year has a negative effect on economic growth in Indonesia, while the carbon emission variable (in the previous 1 year, 2 years earlier, and 3 years earlier) has a positive effect on economic growth in Indonesia. Then, the greenhouse gas emission reduction variable (in the current year and 3 years earlier) has a negative effect on economic growth in Indonesia, while the greenhouse gas emission reduction variable (in the previous 1 year and 2 years earlier) has a positive effect on economic growth in Indonesia. In the long run, the energy consumption variable has a positive effect on economic growth in Indonesia, while the carbon emission variable and the greenhouse gas emission reduction variable have a negative effect on economic growth in Indonesia.

Keywords: Energy Consumption; Carbon Emissions; Greenhouse Gas Emissions Reduction; Economic Growth

1. Introduction

The economy can never be separated from the life of a country. Every government has a goal to grow its country's economy. According to [1] economic growth is an effort to increase production capacity to achieve additional output, which is measured using Gross Domestic Product (GDP) or using Gross Regional Domestic Product (GRDP) in a region. Economic growth is used as an indicator of economic success in a country. To drive a country's economic growth, production activities require the use of significant natural resources. However, the overuse of these resources has a negative impact on the environment both now and in the future. Some of the impacts of overuse of natural resources are forest loss, climate change and so on. Forests are the lungs of the world that function as carbon sinks in the air. Apart from being a carbon sink in the air, forests in Indonesia also function in economic activities, where forest and land products are used in the economy.

On the other hand, energy use also plays a role in economic growth. As a country with a large area and a large population, Indonesia requires the use of energy to drive the economy. Energy use in Indonesia is quite large due to the large number of industrial activities. Efficient energy consumption is needed to grow the economy sustainably. In addition, massive economic growth efforts will bring other environmental degradation impacts such as the emergence of carbon emissions (CO2). Carbon emission is the release of carbon dioxide gas into the earth's atmosphere which causes certain effects such as the formation of greenhouse gases and air pollution. Carbon emissions are caused by the use of large amounts of non-renewable energy and deforestation. In line with carbon emissions, greenhouse gas emissions also arise as a result of massive economic growth. Industrialization and deforestation have also increased greenhouse gas emissions. In recent decades, the Indonesian government has made efforts to reduce greenhouse gas emissions in growing the country's economy. According to [2], the Indonesian government seeks to achieve Net Zero Emission (NZO) by 2060 or sooner. In achieving the zero emission target, the government

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is implementing five main principles, namely increasing the use of new renewable energy (EBT), reducing fossil energy, electric vehicles in the transportation sector, increasing the use of electricity in households and industries, and using Carbon Capture and Storage (CCS). These efforts are being made so that Indonesia's economic growth can be maintained. Through this research, it is expected to provide a complete picture of the effect of energy consumption, carbon emissions, and greenhouse gas emissions reduction on Indonesia's economic growth.

2. Literature Review

2.1 Energy Consumption

Energy consumption is an important indicator of a country's development. According to [3] energy is the ability to rearrange a material, or in other words, energy is the capacity to do a job. Energy is needed in almost every production activity, both goods and services. Energy can be divided into two types, namely renewable energy and non-renewable energy. Renewable energy is energy that comes from sources that can be renewed naturally in a relatively short period of time or continuously exist such as wind, water, geothermal, solar, and biomass. While non-renewable energy is energy that comes from sources whose availability is limited and requires a very long time to re-form such as coal, petroleum, natural gas and also nuclear materials such as uranium. Energy consumption is needed in various sectors to drive the country's economy. However, in its use, attention is needed to avoid energy exploitation. The energy used must be efficient and not excessive so that it does not have a negative impact in the future.

2.2 Carbon Emissions

Carbon emissions are the rate at which carbon dioxide gas is released into the atmosphere as a result of human activities. Carbon emission intensity is used to measure the level of carbon emissions in a country. Rapid economic growth is often followed by greater consumption of energy and natural resources, causing carbon emissions to increase. Carbon emissions have an impact on public health such as causing respiratory diseases. According to [4], air pollution caused by carbon emissions in the long term can increase the risk of respiratory infections, heart disease and lung cancer. Several studies have shown a relationship between energy consumption and economic growth. According to [5], in his research on economies in developing countries, found a relationship between energy consumption and economic growth.

2.3 Greenhouse Gas Emissions Reduction

Greenhouse gas emissions are emissions formed due to the composition of gases that cause the greenhouse effect such as Methane (CH4), Nitrogen Oxide (N2O), Carbon Dioxide (CO2), and other substances that are pollutants. Greenhouse gas emission reduction is the level of reduction in greenhouse gas emissions. Research by [6] shows that in the long run, countries that adopt appropriate emission reduction policies can experience sustainable economic growth, especially through increased energy efficiency and technological innovation. The relationship between greenhouse gas emission reduction and economic growth is complex and highly influenced by factors such as technology, government policies, and economic structure. While there is a view that emission reductions can hinder economic growth, with technological innovation, energy transition and appropriate environmental policies, countries can achieve sustainable economic growth while reducing greenhouse gas emissions.

2.4 Economic Growth

Economic growth is one indicator of a country's success in carrying out economic processes and activities. The economic growth rate shows the percentage increase in real national income in a given year when compared to real national income in the previous year. Economic growth also reflects the condition of economic activity in a country, which in this case is how far the people in a country produce goods and services within a certain period of time. According to [7], there are 3 factors in economic growth in each country, namely:

1. Capital accumulation, including all types of new investment invested in new factories, land, physical equipment and the division of human resources can also improve its quality, so that in the end it will have the same positive impact on production figures. Capital accumulation occurs when a portion of income is reinvested with the aim of increasing future output or income.
2. Population growth (growth in population) means that population growth is followed by labour growth as one of the positive factors that spur economic growth.
3. Technological progress (technological process) is the most important source of economic growth, because technological progress brings modernisation so as to increase economic growth rapidly.

2.5 Environmental Kuznet Curve

The environmental Kuznet curve (EKC) theory was created by Grossman & Krueger in 1991 by applying the Kuznet hypothesis to determine the relationship between economic growth and environmental conditions. The theory explains that in the early stages of economic development, a country's emissions will increase due to high levels of energy consumption and industrialization. However, after reaching a certain income level, a country's emissions will decrease due to the transition to cleaner

technologies and stricter environmental policies. The Environmental Kuznet Curve hypothesis that economic growth will increase environmental degradation because it focuses only on increasing repetitive production, which results in environmental pollution. At some point, people will realize the importance of good environmental quality. From this point, there will be a turning point where economic growth will decrease environmental degradation [8].

3. Research Method

This type of research is quantitative or uses numerical data in conducting statistical analysis to test the research hypothesis. The data used in this research is secondary data in the form of time series. The data obtained will be measured using statistical methods to test hypotheses regarding the effect of energy consumption, carbon emissions, and greenhouse gas emission reduction on Indonesia's economic growth. The research method used is the Autoregressive Distributed Lag (ARDL) model with time series data from 1991 to 2020.

This research uses a quantitative approach. The quantitative approach is a systematic scientific research approach to several parts, phenomena and also interconnected causality [9]. The method used in this research is Autoregressive Distributed Lag (ARDL). ARDL is one of the econometric methods that assumes that a variable is influenced by the variable itself for the past time. (lag variable). The ARDL model is a combination of the Auto Regressive (AR) and Distributed Lag (DL) models. The AR model is a model that uses one or more than more past data from the dependent variable. The AR equation model is as follows:

$$Yt = \beta 1 + \beta 2Xt + \beta 3Zt + \beta 4Yt - 1 + ut$$

Description :
Yt = dependent variable at time t of observation
Xt = independent variable
Zt = independent variable
Yt-1 = dependent variable at time t-1 of observation
β1, β2, β3 = slope of the regression line
ut = error

While the DL model is a regression linking data at the present time and past time (lagged) of independent variables [10]. The DL equation model is as follows:

$$Yt = \propto + \beta 0Xt + \beta 1Zt + \beta 2Xt - 1 + \beta 3Xt - 1 + \beta 4Xt - 2 + \beta 5Xt - 2 + \cdots \beta kXt - k + ut$$

This DL model shows the delay factor so that the dependent variable and the independent variable are not simultaneous. This model is called a dynamic model (a model that involves changes over time) due to the effect of changing the unit value of the independent variable within a certain period of time.

4. Results and Discussions

4.1 Unit Root Test

Stationary test (unit root test) is an initial test of time series data that will be used in research to see whether the data is stationary or not. In the stationary test that has been carried out, the following results are obtained:

Table 4.1 Chow Test

Variable	Probability	Description
Economic Growth	0.0144	Stationary
Energy Consumption	0.0010	Stationary
Carbon Emissions	0.0000	Stationary
Greenhouse Gas Emissions Reduction	0.0000	Stationary

Source: Researcher Processed Data (2024)

Based on table 4.1, the unit root test results show that the economic growth variable is stationary at the first difference level with a probability value of 0.0144. The energy consumption variable is stationary at the first difference level with a probability value of 0.0010. Then the carbon emission variable is stationary at the first difference level with a probability value of 0.0000. Greenhouse gas emission reduction variable is stationary at the first difference level with a probability value of 0.0000. It can be concluded that all variables are stationery at the first difference level because the probability value is smaller than the α value of 5% so that testing can be continued to the next step.

4.2 Lag Optimum Test

After conducting the unit root test, the next step in the ARDL model is the optimum lag. The optimum lag test is used to see the best lag length in the ARDL model used. The shorter the lag, the better the ARDL model. The optimum lag results obtained after testing the E-views application are as follows:

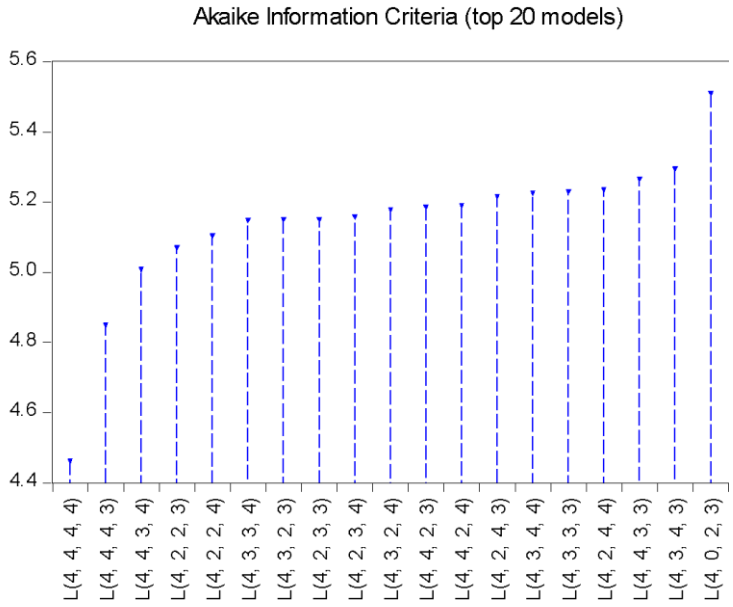

Figure 4.1 Lag Optimum Result
Source : Researcher Processed Data (2024)

Based on the results of the tests conducted, the estimation results of lag selection criteria were obtained by looking at the Akaike Information Criteria (AIC). The results show that the best criterion is ARDL(4, 4, 4, 4), meaning that the economic growth variable (Y) with 4 lags, the energy consumption variable (X1) with 4 lags, the carbon emission variable (X2) with 4 lags, and the greenhouse gas emission reduction variable (X3) with 4 lags. After the optimum lag is obtained, we can proceed to the next step.

4.3 Bound-Test Cointegration

Table 4.2 Bound-Test Cointegration

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	5.386376	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Source : Researcher Processed Data (2024)

Based on the bound-test cointegration results, the F-statistic value is 5.386376. The F-statistic value is greater than the critical I (1) value at α 5% which is 3.67 so it can be concluded that there is cointegration in the ARDL model. If the unit root test, lag optimum, and bound-test cointegration have been conducted and have met the requirements, then the ARDL model is appropriate to be used for forecasting.

4.4 Stability Test

The model stability test is conducted to see the stability of parameters in the short and long term. The model is considered stable if the blue line is between the red lines and does not cross the red line in the CUSUM Test and CUSUM of Squares Test. The following are the results of the CUSUM Test and CUSUM Of Squares Test of the variables used in the study:

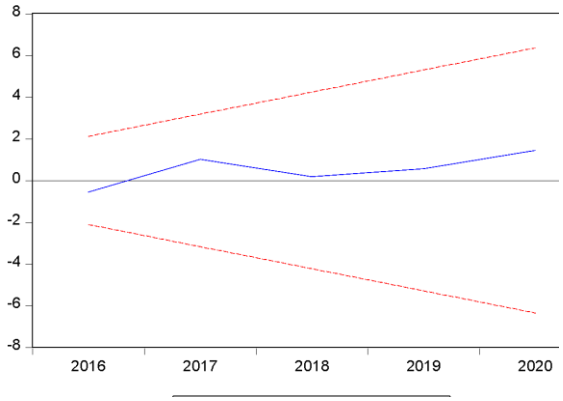

Figure 4.2 CUSUM Test
Source : Researcher Processed Data (2024)

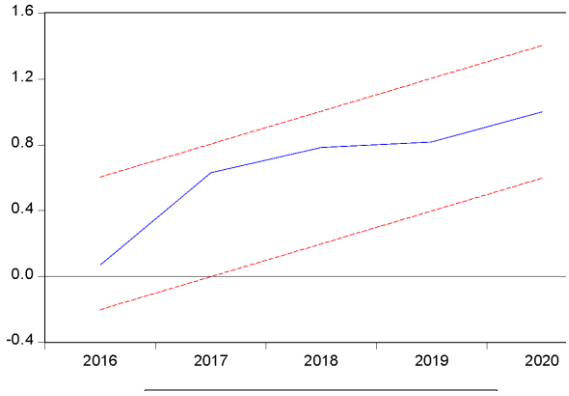

Figure 4.3 CUSUM Of Squares Test
Source : Researcher Processed Data (2024)

Based on Figure 4.2 and Figure 4.3, it shows that the CUSUM Test and CUSUM of Squares Test lines are between the red lines (5% significant) and do not cross the two red lines. This means that the ARDL model used is stable, both in terms of parameters and residual variances.

4.5 ARDL Model

4.5.1. Short Term Equation

To see the effect of independent variables on the dependent variable in the short term, it is necessary to test the short-term equation. In the ARDL model, the short-term effect is done by testing the Error Correction Model (ECM).Error Correction Model (ECM).

Table 4.3 ECM Result

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(Y(-1), 2)	22.57852	3.254821	6.936946	0.0010
D(Y(-2), 2)	15.89679	2.843253	5.591057	0.0025
D(Y(-3), 2)	8.901015	1.253073	7.103347	0.0009
D(X1, 2)	0.017065	0.002619	6.516176	0.0013
D(X1(-1), 2)	-0.051074	0.008652	-5.902901	0.0020
D(X1(-2), 2)	-0.029927	0.006318	-4.736859	0.0052
D(X1(-3), 2)	-0.015937	0.002977	-5.353503	0.0031
D(X2, 2)	-425.3049	85.25238	-4.988775	0.0041
D(X2(-1), 2)	897.0580	155.1865	5.780514	0.0022
D(X2(-2), 2)	541.6338	107.8230	5.023362	0.0040
D(X2(-3), 2)	211.0423	45.56610	4.631564	0.0057
D(X3, 2)	-0.064043	0.007106	-9.012328	0.0003
D(X3(-1), 2)	0.119719	0.016912	7.079063	0.0009
D(X3(-2), 2)	0.010895	0.001810	6.018675	0.0018
D(X3(-3), 2)	-0.006515	0.001719	-3.789491	0.0128
CointEq(-1)*	-24.23499	3.480753	-6.962570	0.0009

R-squared	0.982035	Mean dependent var	-0.310800
Adjusted R-squared	0.952093	S.D. dependent var	7.706128
S.E. of regression	1.686697	Akaike info criterion	4.141770
Sum squared resid	25.60453	Schwarz criterion	4.921851
Log likelihood	-35.77213	Hannan-Quinn criter.	4.358132
Durbin-Watson stat	2.193019		

* p-value incompatible with t-Bounds distribution.

Source : Researcher Processed Data (2024)

After analyzing the data to see the short-term effects, the following results were obtained:

1. Energy consumption in the short term has a positive and significant effect on economic growth. A one-period lag change of the energy consumption variable has a negative and significant effect on the economic growth variable. This result shows a change in the effect from the previous period which was initially positive to negative. This means that there is a follow-up effect of changes in energy consumption in the previous period that makes the effect reverse direction. The two-period lag change of the energy consumption variable has a negative and significant effect on the economic growth variable. The negative value indicates that changes in the previous period still have a negative effect on this period. Changes in the three-period lag of the energy consumption variable have a negative and significant effect on the economic growth variable.
2. The carbon emission variable has a negative and significant effect on the economic growth variable. A one-period lag change of the carbon emission variable has a positive and significant effect on the economic growth variable. This means that in one previous period there was a change in influence from negative to positive. A two-period lag change of the carbon emission variable two periods earlier has a negative and significant effect on the economic growth variable. Changes in the three-period lag of the carbon emission variable have a positive and significant effect on the economic growth variable.
3. Greenhouse gas emission reduction variable has a negative and significant effect on economic growth variable. A one-period lag change of the greenhouse gas emission reduction variable has a positive and significant effect on the economic growth variable, meaning that there is a change in influence from negative to positive. A two-period lag change of the greenhouse gas emission reduction variable has a positive and significant effect on the economic growth variable, indicating that the effect in the previous period still continues in this period. A three-period lag change of the X3 variable has a negative and significant effect on the Y variable, meaning that there is a change in influence again in this period from initially having a positive effect to having a negative effect.

4.5.2. Long Term Equation

To see the effect of the independent variable on the dependent variable in the long run, the long run test is conducted. The long run test results obtained are as follows:

Table 4.4 Long Run Test

Levels Equation

Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(X1)	0.002835	0.000424	6.681029	0.0011
D(X2)	-74.53740	7.847397	-9.498359	0.0002
D(X3)	-0.011434	0.000646	-17.69257	0.0000
C	-0.605742	0.074899	-8.087468	0.0005

EC = D(Y) - (0.0028*D(X1) -74.5374*D(X2) -0.0114*D(X3) -0.6057)

Source : Researcher Processed Data (2024)

The long run test that has been conducted shows the following results:

1. Energy consumption variable has a positive and significant effect on economic growth variable in the long run. If the value of energy consumption increases, then economic growth will also increase.
2. Emission variables have a negative and significant effect on economic growth variables in the long run. When carbon emissions increase, it will cause the value of economic growth to decrease.
3. The greenhouse gas emission reduction variable has a negative and significant effect on the economic growth variable in the long run. An increase in greenhouse gas emission reduction will cause a decrease in the value of economic growth.

5. Conclusions

Based on the results of the analysis conducted using the Autoregressive Distributed Lag (ARDL) model, the conclusions of this study are as follows:

1. For the short term, energy consumption variables in the current year have a positive effect on economic growth in Indonesia, while energy consumption variables (in the previous 1 year, 2 years earlier, and 3 years earlier) have a negative effect on economic growth in Indonesia. For the long term, energy consumption has a positive and significant effect on economic growth in Indonesia.
2. In the short term, the carbon emission variable in the current year has a negative effect on economic growth in Indonesia, while the carbon emission variable (in the previous 1 year, 2 years earlier, and 3 years earlier) has a positive effect on economic

growth in Indonesia. For the long term, carbon emissions have a negative and significant effect on economic growth in Indonesia.

3. In the short term, the greenhouse gas emission reduction variable (in the current year and 3 years earlier) has a negative effect on economic growth in Indonesia, while the greenhouse gas emission reduction variable (in the previous 1 year and 2 years earlier) has a positive effect on economic growth in Indonesia. In the long run, the reduction of greenhouse gas emissions has a negative and significant effect on economic growth in Indonesia.

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