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THE IMPACT OF ELECTRICITY, CO_2 EMISSIONS, AND FOSSIL ENERGY ON INDONESIA'S ECONOMIC GROWTH

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Abstract
This study aims to analyze Electrical Energy, CO_2 Emissions and Fossil Energy on Economic Growth in Indonesia. This study uses secondary data from 1980-2023 obtained from the Central Statistics Agency. The data analysis method is the Autoregressive Distributed Lag. The results of the study show that in the short term, electrical energy shows a significant negative effect on economic growth. While CO_2 emissions and fossil energy show a significant positive effect on economic growth. In the long term, electrical energy, CO_2 emissions and fossil energy do not show a significant effect on economic growth.

Keywords: ***Electrical Energy, CO_2 Emissions and Fossil Energy on Economic Growth.***

INTRODUCTION

Economic growth serves as a fundamental indicator for assessing a country's economic performance. It reflects the extent to which economic activities drive increases in household income over a given period. Furthermore, economic growth demonstrates an economy's capacity to sustainably provide goods and services required by households, businesses, and the government (Zuldareva, 2023). Economic growth not only serves as a measure of a country's economic achievement but also as a critical component in development planning and policy. Understanding the rate of economic growth helps policymakers identify areas that require economic stimulus, adjust monetary and fiscal policies, and design strategies to strengthen electricity resources and human capital. Therefore, monitoring economic growth is essential to ensure that the implemented policies can promote sustainable increases in production, consumption, and investment, which will ultimately have a positive impact on the overall welfare of society. (Mukhtarov et al., 2023). The development of Indonesia's economic growth from 1980 to 2023 is as follows:

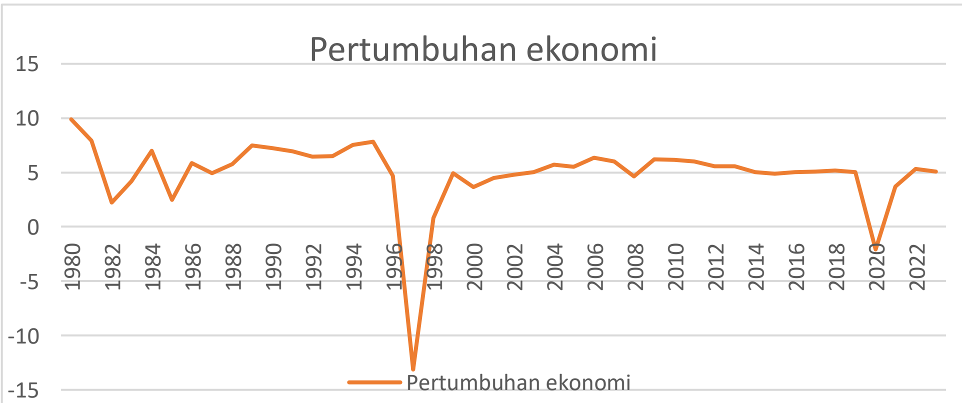

Image 1. economic growth from 1980 to 2023

The economic growth chart of Indonesia from 1980 to 2023 illustrates various trends influenced by global conditions and domestic policies. The Asian Financial Crisis in 1997 and the COVID-19 pandemic in 2020 represent two major events that triggered significant declines in Indonesia's economic growth. In 1997, the Asian Financial

Crisis was triggered by the devaluation of Thailand's baht, which subsequently spread to neighboring countries, including Indonesia. As a result, Indonesia's economic growth contracted sharply to -13.13% in 1998.

Energy is a fundamental necessity for humans, with demand continuously increasing alongside rising living standards. Energy is vital to various human activities, as nearly all processes require energy. It plays a crucial role in human life, with a very high degree of dependency. As demand grows due to population increases, industries are required to enhance productivity and efficiency. Moreover, the depletion of fossil fuel reserves and the ongoing rise in energy consumption contribute to resource scarcity. Energy consumption serves as a key driver of economic industrialization and functions as a means of capital accumulation for development. It plays both complementary and substitutive roles in generating outputs within the economy (A'nnisa et al., 2020).

Improvements in efficiency and production capacity can increase a country's total economic output, as measured by Gross Domestic Product (GDP). Therefore, there is a direct relationship between the amount of energy consumed and the value added generated within the economy. The development of electricity consumption in Indonesia during the period from 1980 to 2023 is as follows:

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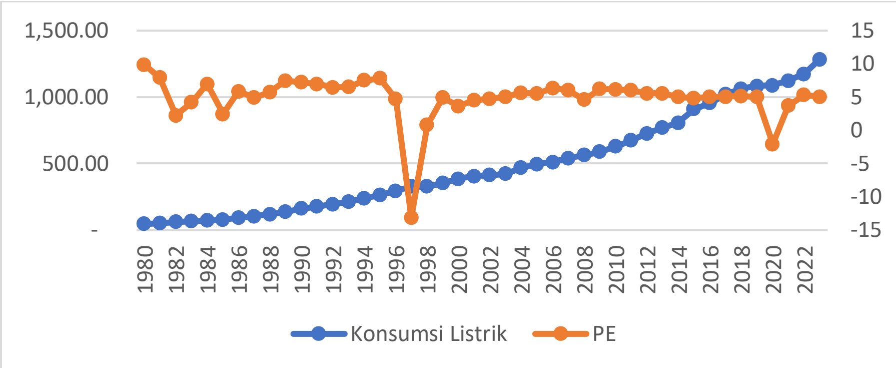

Image 2 Electricity Consumption (kWh) and Economic Growth (%) in Indonesia, 1980–2023

Based on Table 1.2, the graph of electricity consumption in Indonesia from 1980 to 2023 shows a consistent and significant increase. In 1981, electricity consumption reached 146 kWh, rising to 1990, reflecting economic growth and the implementation of national electrification programs. In the following decade, electricity consumption increased at a faster pace, from 164 kWh in 1991 to 303 kWh in 2000, despite the economic crisis of the late 1990s. The period from 2001 to 2010 experienced a sharp rise from 337 kWh to 708 kWh, driven by rapid urbanization and increasing household purchasing power. Lastly, from 2011 to 2022, electricity consumption surged from 809 kWh to 1,285 kWh, fueled by population growth, the expansion of the industrial sector, government electrification policies, and shifting consumption patterns during the COVID-19 pandemic. From the data above, it is also evident that fluctuations in electricity consumption tend to correlate with changes in economic growth. However, certain years indicate anomalies where higher electricity consumption coincided with a decline in economic growth, and vice versa (Kemenkeu, 2024).

The increase in electricity consumption reflects economic growth and modernization, where electricity becomes increasingly integrated into daily life, supporting industry, households, and transportation. Theoretically, rising electricity consumption can drive economic growth. Higher electricity usage enhances productivity in production processes, powers industrial and manufacturing sectors, and fosters technological innovation.

As noted by Zuldareva, (2023), high levels of electricity consumption are often associated with CO_2 emissions issues. CO_2 emissions are one of the main greenhouse gases contributing to global climate change (Munir et al., 2020). In Indonesia, the majority of electricity is still generated from fossil fuel combustion, such as coal and oil, which leads to increasing CO_2 emissions. This raises concerns regarding negative environmental and public health impacts, as well as potential long-term consequences for sustainable economic growth

The positive impact of CO_2 emissions is the increase in production and economic activities. The use of energy derived from fossil fuels has been a major driver of industrialization and economic growth in many countries. This energy enables mass production, efficient transportation, and widespread access to electricity, all of which support increased productivity and economic welfare. Meanwhile, the negative impact of CO_2 emissions arises from the combustion of fossil fuels, which contributes to air pollution and climate change. These impacts can result in significant economic costs, including damage to electricity infrastructure due to extreme weather, decreased agricultural yields, and higher healthcare costs due to air pollution. Furthermore, another negative impact is the dependence on fossil fuels, which can lead to economic instability in the event of oil price fluctuations or disruptions in energy supply. Countries that lack their own fossil energy resources may experience trade deficits and high dependence on energy imports.

The development of CO_2 emissions in Indonesia during the period 1980–2023 is as follows:

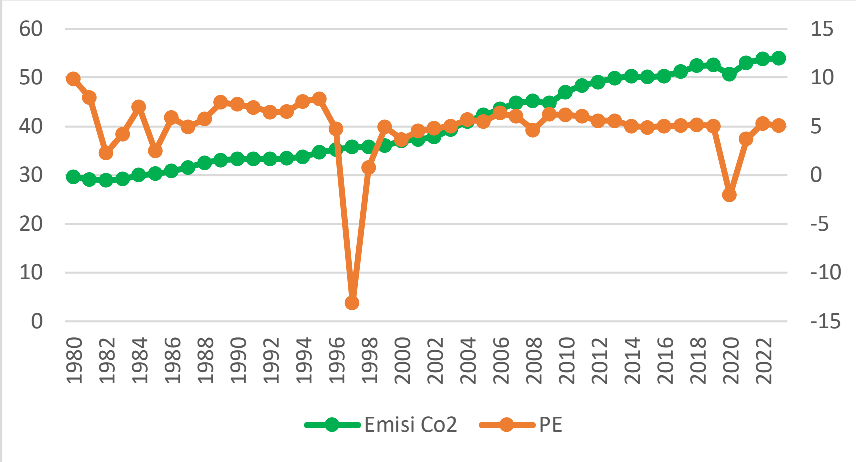

Image 3. Emisi CO_2 di Indonesia 1980-2023 (%)

Based on image 3 above, the graph of CO2 emissions in Indonesia from 1980 to 2022 shows a consistent and significant upward trend. In the early period, throughout the 1980s and 1990s, emissions reached around 37.85% in the year 2000. This increase aligns with economic growth, industrial expansion, and rising energy consumption.

. The use of fossil fuels, such as coal and petroleum, has been a primary focus in the context of economic growth in Indonesia. Although fossil energy sources still dominate, there is growing awareness of the importance of shifting to more environmentally friendly energy sources. This shift is driven by awareness of the negative environmental and health impacts caused by fossil fuel combustion, such as air pollution and global warming. Therefore, policy changes and investments in renewable energy are key to creating sustainable economic growth.

One important step in reducing dependence on fossil energy is to increase the utilization of renewable energy, such as solar power, wind, and biomass. Indonesia has great potential for developing renewable energy, supported by abundant natural resources and favorable geographic conditions. By tapping into this potential through investment and supportive policies, Indonesia can reduce greenhouse gas emissions while creating new jobs in the renewable energy sector (Joo et al., 2015).

In addition to environmental benefits, investment in renewable energy can also drive economic growth through job creation, the development of new industries, and increased global competitiveness. The renewable energy industry can also become a significant source of revenue through the export of renewable energy technologies and products. Thus, policy reforms that support investment in renewable energy will have long-term positive impacts on Indonesia's economic growth (Joo et al., 2015).

However, the transition to renewable energy also faces challenges, including inadequate electricity infrastructure, technological limitations, and resistance from parties still reliant on fossil fuels. Therefore, cooperation among the government, private sector, and society is essential to create an environment that supports the development of renewable energy. The development of fossil energy data during the 1980–2023 period can be seen in the following graph:

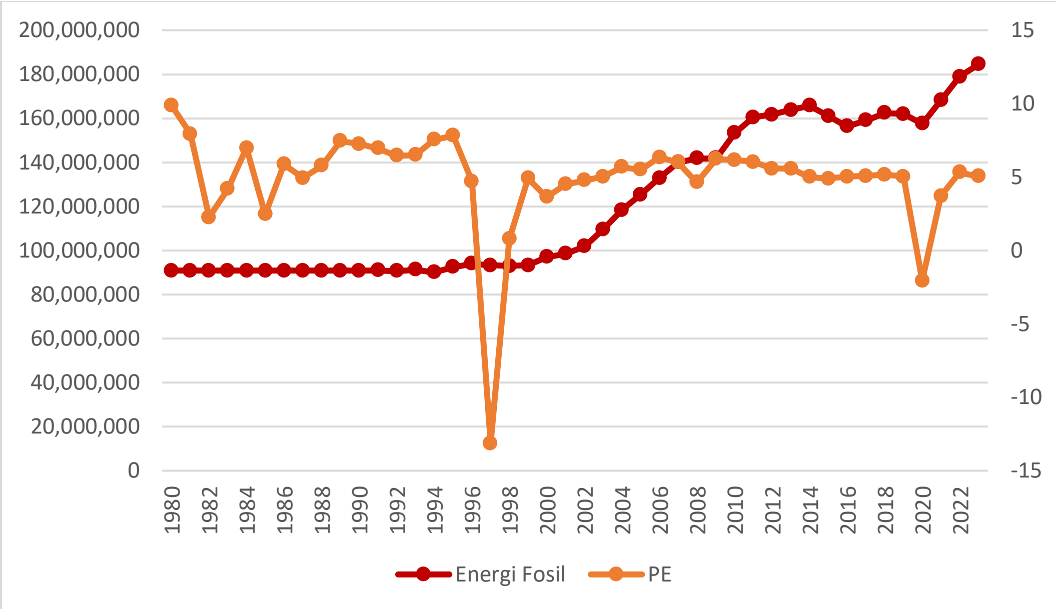

Image 4 Energi Fosil di Indonesia 1980-2023 (Ton)

Based on the graph, the development of electricity consumption in Indonesia from 1980 to 2023 shows a fluctuating pattern, influenced by economic conditions and global events. In 1980, growth became more moderate and tended to stabilize above 10 Tons. However, the 1998 Asian financial crisis led to a decline in electricity consumption, dropping to -0.20 Tons. In 2000, the growth trend slowed, showing lower figures compared to previous years, while the 2010 period indicated relatively stable but gradually weakening growth, particularly in 2020 due to the COVID-19 pandemic. Based on the background and phenomena described above, the author is interested in further analyzing "The Analysis of Electricity Energy, CO2 Emissions, and Fossil Energy on Economic Growth in Indonesia."

LITERATURE REVIEW

Economic Growth

Sukirno, (2021) states that economic growth is the change in the level of economic activity that occurs from year to year. To measure this growth, it is necessary to compare the country's national income from one year to another, which is commonly referred to as the economic growth rate.

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Energy Listrik

Electricity is an essential form of energy, as it is used for various activities in daily life. Without electricity, activities would be disrupted, both in the economic and social sectors (Rosmeli, 2018). Access to electricity is one of the fundamental prerequisites for improving the quality of life and strengthening the economic competitiveness of society and the nation. No country in the world can achieve a high level of development and prosperity without ensuring adequate and sustainable electricity access for its people (Christiani & Nainupu, 2021).

CO_2 Emissions

According to Mann (2019), CO_2 emissions are greenhouse gases produced by human activities, primarily from the combustion of fossil fuels and deforestation. Oreskes (2019) states that CO_2 emissions refer to carbon dioxide released into the atmosphere as a result of human activities, including industrial processes and the use of fossil fuels.

Energy Fossil

The use of fossil fuels has led to an energy crisis in various parts of the world. Moreover, the impacts of fossil fuel consumption have been experienced by many countries, one of which is climate change that contributes to global warming. According to Greenpeace (2019), climate change is a consequence of the continuous use of fossil-based fuels such as coal, petroleum, and natural gas by humans. In addition to global warming, the use of fossil fuels also causes pollution in many countries, which ultimately leads to fatalities resulting from the pollution itself.

RESEARCH METHODS

Object of Research

The object of this study is economi growth as the dependent variable, while Electricity Energy, CO_2 Emissions, Fossil Energy are the independent variables. The location in this research is in Indonesia.

Data Types and Sources

This study uses a quantitative method because the research data is in the form of numerical data. This study uses secondary data from 1880 to 2023.

Method of Collecting Data

The method of data collection in this study is using the documentation method. Data and information collection is carried out by obtaining it from the Ministry of Energy and Mineral Resources (KESDM), journals and articles. Then the data will be tested with a statistical tool, namely eviews 10.

Data Analysis Method

The data analysis method used in this study if it meets the requirements for using the ARDL model, then the author will process the data using the ARDL model. This research uses quantitative analysis methods, namely time series data. By using quantitative data analysis ARDL method in processing data, it can find out how the independent variable (independent variable) can affect the dependent variable (dependent variable). This analysis method is used to determine the effect of the dependent variable and the independent variable in the long or short term. This ARDL model was chosen because this model can overcome research variables/data that have different stationary levels (Siti Afifatul Farichah, 2022).

ARDL is considered effective in determining short-term and long-term relationships between variables that do not have the same integration order where the variables are stationary at level I(0), First Difference I(1) simultaneously.

In general, the steps that will be taken for econometric analysis using this method are as follows: Testing the stationarity of variable data in the research model, both at the level and first difference levels, Classical assumption test, Optimum lag determination test, Cointegration test, ARDL model estimation in the long term and short term, and ARDL Model Stability Test.

Stationery Test

Stationarity is one of the important requirements that must be met. A data is said to be stationary if the mean and variance of the data are constant or do not change systematically over time. One of the formal procedures for stationarity testing is the unit root test. This test was developed by David Dickey and Wayne Fuller and is called the Augmented Dickey-Fuller (ADF) Test. If a time series data is not stationary at the level (zero order, I(0)), then the stationarity of the data can be sought through the next order, namely the first order or I(1) (first difference), or the second order I(2) (second difference). Since this study uses the ARDL method, all variables must be stationary at the level (I(0)) or first order (I(1)).

Classical Assumption Test

Classical assumption tests look for problems in the data collected in this study to determine that it is normally distributed and worthy of further investigation. Classical hypothesis testing is seen based on the normality test, autocorrelation test and heteroscedasticity test.

Normality Test

The normality test is carried out with the aim of testing whether the model to be regressed is normally distributed or not. This study uses the Jarque-Bera (JB) test method to determine whether the regression model is normal or not. By comparing the calculated JB value with an alpha level of 0.05 (5%). If the Jarque Bera (JB) probability value is greater than 5% (0.05), then the data is normally distributed.

Autocorrelation Test

According to Gujarati & Porter (2012) autocorrelation is defined as the correlation between members of a series of observations organized by time (time series data) and by space (cross-section data). Gujarati (2015) to test the presence or absence of aultocorrelation uses two ways, the Dorbin-Watson Test and the Breusch-Godfrey Test. In this study, the Breusch-Godfrey Serial Correlation LM Test method was used. With conditions if:

1.Probability> from $\alpha = 5\%$, it means there is no autocorrelation, and vice versa if
2.The probability value < than $\alpha = 5\%$, means there is autocorrelation.

Heteroskedasticity Test

Heteroscedasticity is a condition where the variation of residuals is not constant. A good regression model is homoscedasticity or no heteroscedasticity. The heteroscedasticity test used in this study is the Breusch-Pagan-Godfrey test. How to detect the Breuschpagan-Godfrey test method by looking at the 0bs * R-squared and Chi-Squares values with conditions if:

1. Obs*R-squared value> Chi Squares value, The probability of the Chi Squares value> 0.05 indicates that there is no heteroscedasticity in the model.
2. If the Obs*R-squared value < Chi Squares value and the probability of the Chi Squares value < 0.05 indicates heteroscedasticity in the model.

Determination of Optimum Lag

Determining the optimal lag is very important in order to obtain the dynamics of the system to be modeled. If the lag is too long, it will result in more parameters that must be estimated so that it can reduce the ability to reject H0 because too many additional parameters will reduce the degree of freedom. Determining the optimal lag length can utilize some information, namely by using the Akaike Information Criterion (AIC). AIC penalizes additional variables (including lag variables) that reduce the degree of freedom. Therefore, the lag will be found in the model specification that gives the minimum AIC value.

Cointegration Bound Test

The cointegration test is a test of whether there is a long-term relationship between the independent and dependent variables, this test is a continuation of the unit root test and the integration test. Cointegration testing is done using the bound test. The decision-making requirement in the cointegration test using the bound test compares the F-statistic value with the critical value of the lower and upwer bounds. If the F-statistic value is higher than the critical value of the upwer bound then Ha is accepted (Ha = there is cointegration between variables), and if the F-statistic value is smaller than the critical value then Ho is accepted (Ho = there is no cointegration between variables).

ARDL Model

The Autogressive Distributed Lag (ARDL) model represents the interaction between X and Y variables over time, including the impact of past values of Y variables on the current value of Y. The Autogressive Distributed Lag (ARDL) model is used in this investigation.

In general, the ARDL model equation can be written as follows:

$$\boldsymbol{\Delta Yt = \beta_0 + \sum_{i=1}^{n} \beta_1\, \Delta Y_{t-1} + \sum_{i=1}^{n} \delta_1 \Delta X_{t-1} + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-1} + \mu t}$$

Description:
β_1, δ_1 : Short-term coefficient
φ1, φ2 : Long run coefficient
μt : Disturbance error (whitenoise)
The following is the general model of ARDL:

$$\Delta PE\ t = \beta 0 + \sum_{z=1}^{n} \beta 1 \Delta\, PE_{t-1} + \sum_{i=0}^{n} \beta 2\ \ \Delta KL_{t-1} + \sum_{i=1}^{n} \beta 3\ \Delta CO2_{t-I} + \sum_{i=1}^{n} \beta 4\ \Delta EF_{t-I} + et$$

Description:
β_1, δ_1 = Short-term coefficient
φ1, φ2 = Long run ARDL coefficients
PE_t = Economic Growth

KL_t = Electricity Energy
CO_{2t} = CO_2 Emissions
EF_t = Fossil Energy
μt = Disturbance error (whitenoise)

The estimation method used is the Autoregressive Distributed Lag (ARDL) approach. The ARDL model was chosen because using ARDL will be able to see the effect of Y and X over time, as well as the effect of past Y variables on present Y.

Model Stability Test

The ARDL model stability test in this study uses the cusum test where the cusum test is carried out by looking at the 95% confidence level. The Cusum test results for the ARDL model in this study are determined by the position of the blue Cusum line between the two red 5% significance lines. For the ARDL model, the Cusum line is between the significance lines which proves that the ARDL model is stable.

RESULTS AND DISCUSSION

Data Stationery Test

To determine the stationarity of the data, the Augmented Dicky-Fuller (ADF) Test or the Phillips-Perron (PP) Test is used (Faudzi & Asmara, 2023). Stationary or not will be seen from the probability value (Critical Value) which is compared at the alpha level (1%, 5%, or 10%).

Table 1
Stationarity Test Using Augmented Dickey-Fuller (ADF)

Variabel	Unit Root Test	ADF Test Statistik	Critical Value 5%	Prob	Keterangan
PE	Level	-5.116353	-3.592462	0,0001	Stationer
EL	Level	-5.788619	-3.592462	0,0000	Stationer
CO_2	Firs Different	-5.669304	-3.596616	0,0000	Stationer
EF	Firs Different	-3.523098	-3.596616	0,0121	Stationer

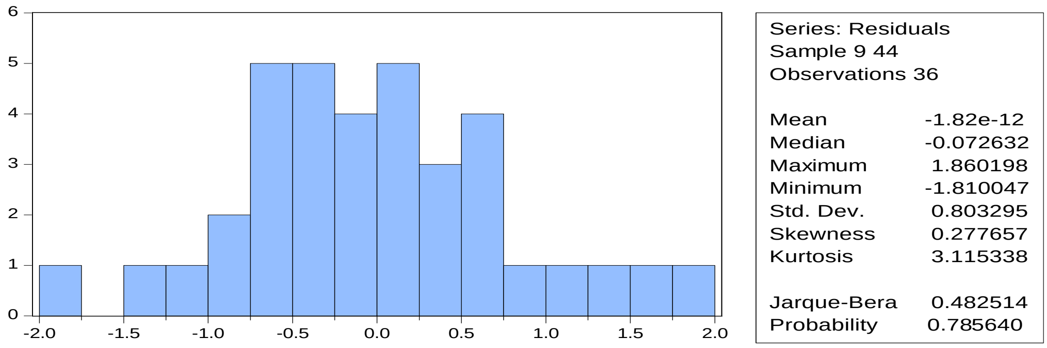
Source: Processed data, eviews10 output results (2024)

Based on Table 1 above, the probability is significant at the 5% level, indicating that the data is stationary at the level for the variables of economic growth and electricity energy, while the variables are stationary at the first difference for CO2 emissions and fossil energy

Classical Assumption Test

The classical assumption test looks for confounding issues in the data collected for this study to determine that it is normally distributed and worthy of further investigation. Multicollinearity test, autocorrelation test and heteroscedasticity test are some examples of traditional assumptions in this subject. The findings of the study's classical assumption tests are as follows:

Normality Test Result



Source: Processed data, eviews10 output results (2024)

Image 5 Normality Test Result

Based on Image 6 shows the results of the normality test using the Jarque Bera (JB-Test) method. The test results resulted in a probability value of 0.785640> 0.05. Based on these results, it can be concluded that the data is normally distributed.

Autocorrelation Test Result

Table 2
Autocorrelation Test Results

F-statistic	0.580398	Prob. F(2,40)	0.5643
Obs*R-squared	1.353671	Prob. Chi-Square(2)	0.5082

Source: Data processed from Eviews output (2024)

Based on Table 2 above, it shows that the calculated $\chi 2$ is smaller than the $\chi 2$ table value, which is 1.35 < 5.99. Therefore, it can be concluded that there is no indication of autocorrelation in this study. This is also supported by the probability value of 0.50 > 0.05.

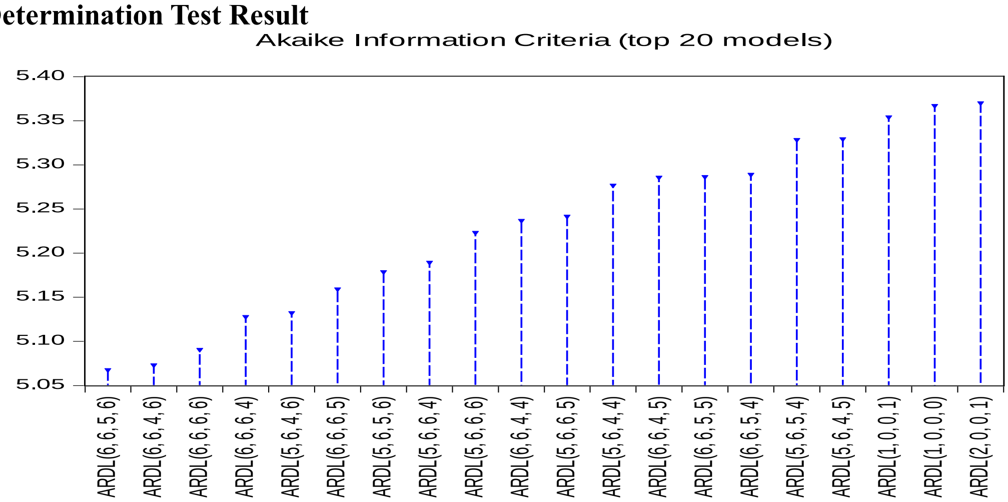
Heteroskedasticity Test Result

Table 3
Heteroscedasticity Test Results

F-statistic	1.154689	Prob. F(26,11)	0.4182
Obs*R-squared	27.81033	Prob. Chi-Square(26)	0.3679
Scaled explained SS	4.823936	Prob. Chi-Square(26)	1.0000

"Based on Table 3, it can be concluded that the heteroscedasticity test results, by observing the Obs*R-squared value of 27.78 and the Chi-Square (33) table value at the 5% significance level of 47.40, show that 27.78 < 47.40. Therefore, this model is free from indications of heteroscedasticity. This is also supported by the Prob Chi-Square value of 0.367 > 0.05.

Optimum Lag Determination Test Result



Source: Processed data, eviews10 output results (2024)

Image 6 Akaike Information Criteria

Based on Figure 6 above, there are 20 top models; however, the most suitable model for the ARDL method in this study is ARDL (6,6,5,6) as it has a smaller error compared to the other ARDL models.

Bound Test Cointegration Result

Table 4
Bound Test Cointegration Results

Test Statistic	Value	K
F-statistic	5.374083	3
Signifikan	I(0)	I(1)
10%	2.37	3.20
5%	2.79	3.67
1%	3.65	4.66

Source: Data processed from Eviews output (2024)

Based on the results of the Bounds Test for the ARDL model in the table above, it can be seen that the F-statistic value of the model is 5.374083, which is greater than the lower bound I(0) value of 2.37 and the upper bound I(1) value of 3.20 at the 10% significance level (5.37 > 2.37 and 5.37 > 3.20). At the 5% significance level, 5.37 > 2.79 (I(0)) and 5.37 > 3.67 (I(1)), and at the 1% significance level, 5.37 > 3.65 (I(0)) and 5.37 > 4.66 (I(1)). Based on the table, these results indicate the presence of long-term cointegration in this model...

ARDL Model Estimation

The data is further checked for cointegration using ARDL analysis following the stationarity test. There are two types of processing viz: short-run processing and long-run processing.

Short-Term Test Results of ARDL Model

Table 5
Short-Term Coefficient Estimation Results of ARDL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(PE(-1))	1.818390	0.379996	4.785291	0.0006
D(PE(-2))	1.494498	0.367133	4.070727	0.0018
D(PE(-3))	0.995547	0.259860	3.831083	0.0028
D(PE(-4))	0.841424	0.224545	3.747238	0.0032
D(PE(-5))	0.327857	0.176250	1.860188	0.0898
D(EL)	-31.70501	19.57249	-1.619876	0.1335
D(EL(-1))	21.06754	22.06727	0.954696	0.3602
D(EL(-2))	70.92169	24.57913	2.885444	0.0148
D(EL(-3))	46.87004	21.42456	2.187678	0.0512
D(EL(-4))	83.15983	18.51131	4.492379	0.0009
D(EL(-5))	103.5707	27.44312	3.774014	0.0031
D(CO2)	273.2894	74.20509	3.682893	0.0036
D(CO2(-1))	-130.1116	63.94485	-2.034747	0.0667
D(CO2(-2))	-91.77718	79.09362	-1.160361	0.2705
D(CO2(-3))	-355.7653	75.24278	-4.728232	0.0006
D(CO2(-4))	-111.4255	87.63068	-1.271536	0.2298
D(EF)	-49.11026	45.62572	-1.076372	0.3048
D(EF(-1))	102.6493	51.42251	1.996193	0.0713
D(EF(-2))	5.351154	55.42649	0.096545	0.9248
D(EF(-3))	256.5792	54.06225	4.745996	0.0006
D(EF(-4))	43.43402	57.87191	0.750520	0.4687
D(EF(-5))	56.12401	23.61161	2.376966	0.0367
CointEq(-1)*	-2.887755	0.477061	-6.053220	0.0001

Source: Data processed from Eviews output (2024)

The value of CointEq (-1)/ECT (-1) is -2.887 and is significant at the 1% level, which indicates the occurrence of both short-term and long-term cointegration in this model. Furthermore, the CointEq (-1) value of -2.887 is used to observe the speed of adjustment in responding to changes. The ECT or CointEq (-1) value is considered valid if the coefficient is negative and significant at the 5% level. In this study, these validity requirements have been met. Therefore, if any disequilibrium occurs in this model, it will be corrected at a speed of 2.887. This finding is supported by the research conducted by Zalretal B (2019).

The analysis shows that the long-term equilibrium correction mechanism is very strong, with a coefficient of -2.887, indicating that 288.7% of the deviation will be corrected in the following period. The EL variable has an insignificant negative effect in the current period but shows a significant positive impact in the 2nd, 3rd, 4th, and 5th periods. CO2 has a significant positive effect in the current period but a significant negative impact in the 1st and 3rd periods. Meanwhile, EF has an insignificant negative effect in the current period but a significant positive impact in the 3rd and 5th periods. This indicates that changes in variables from previous periods can significantly affect PE in the current period.

Long-Term Test Results of ARDL Model

Table 6
Estimation Results of Long-Term Coefficient of ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(EL)	-11.76027	6.717488	-1.750694	0.1078
CO_2	98.50679	60.69667	1.622936	0.1329
LOG(EF)	-31.90044	26.85319	-1.187957	0.2599
C	295.6258	316.1829	0.934983	0.3699

Source: Data processed from Eviews output (2024)

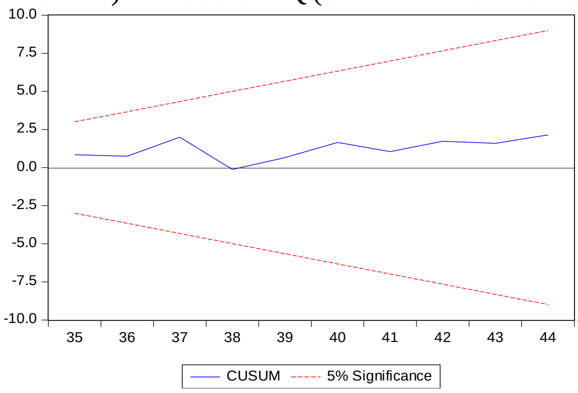
Based on table 6 above, the long-term test of the ARDL model can be formulated as follows:

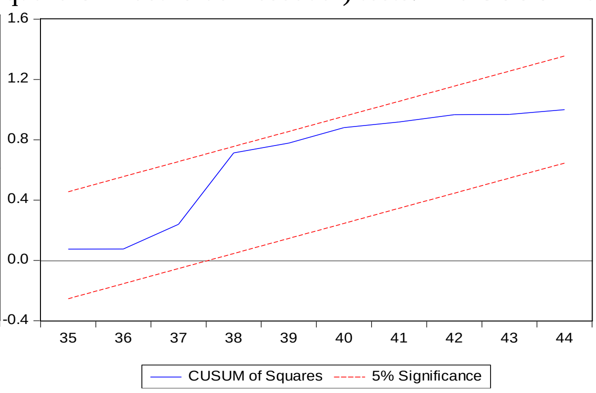
$$\Delta PE = 295.625 - 11.760\ EL_t + 98.506\ CO_{2t} - 31.904\ EF_t$$

The constant value of 295.6258 indicates that when all variables in this study, consisting of electricity consumption, CO2 emissions, and fossil energy, are held constant (fixed), economic growth will remain constant at 295.6258. The electricity consumption variable in the long term is -11.760, which indicates that when electricity consumption increases by 1%, it will decrease economic growth by 11.76%, and this variable has no significant effect on economic growth. The CO2 emissions variable in the long term is 98.50, which indicates that when CO2 emissions increase by 1%, it will increase economic growth by 98.50%, and this variable has a significant effect on economic growth. The fossil energy variable in the long term is -31.900, which indicates that when fossil energy consumption increases by 1%, it will decrease economic growth by 31.90%, and this variable has no significant effect on economic growth.

ARDL Model Stability Test (CUSUM)

Model stability testing can be divided into two, namely the CUSUM (Cumulative Sum of Recursive Resedual) and CUSUM Q (Cumulative Sum Of Square Of Recursive Resedual) tests. The CUSUM test is as follows:





Source: Processed data, eviews10 output results (2024)

Image 8 Uji Cusum Test dan Uji Cusum Q

Based on Image 8 the results of the CUSUM model stability show that the model is in a stable situation and is suitable for use as a reference in determining the long-term relationship between variables. The model stability test results are shown through the CUSUM line (blue) which is still on the 5% significant line (red). The CUSUM Q test results show the same result. This means that the ARDL is declared stable/passes the CUSUM test and all variables are verified.

Effect of Electricity Consumption on Economic Growth

The short-term analysis results indicate that changes in electricity consumption during this period have no significant effect on economic growth, with a coefficient of -31.70501 and a probability value of 0.1335 > 0.05. This suggests that changes in electricity usage have not yet consistently provided a direct impact on economic growth. In the short term, energy infrastructure or distribution remains suboptimal in supporting economic activities that rely on electricity. Although electricity in Indonesia has great potential to support economic growth, its impact is often constrained by inefficient infrastructure, dependence on fossil energy, and challenges in implementing renewable energy policies. Even though renewable energy development efforts are increasing, their contribution to long-term economic growth is still limited due to suboptimal infrastructure and technology. These findings are in line with the study by Anggaini et al. (2021), which concluded that electricity consumption does not affect regional economic growth in Indonesia.

Effect of CO2 Emissions on Economic Growth

The short-term research results show that CO2 emissions during this period and in lag 3 have a significant positive effect with p-values of 0.003 and 0.0006, respectively. This indicates that a 1% increase in CO2 emissions in the current period or one to two previous periods can increase economic growth. This suggests that medium-term investments in high-emission infrastructure projects, such as major construction projects, have a positive impact on economic growth. Meanwhile, CO2 emissions in lags 1, 2, and 4 have no effect on economic growth

In the long term, CO2 emissions have no effect on economic growth. This shows that although CO2 emissions can indicate increased economic activity in the short term, the negative impacts of environmental degradation, public health issues, and natural disasters related to climate change tend to reduce economic benefits in the long run. Furthermore, the slow transition towards a green economy in Indonesia limits the potential positive contributions of more environmentally friendly economic activities. These findings are consistent with the study by Kurniarahma (2020), which concluded that CO2 emissions affect economic growth

Effect of Fossil Energy on Economic Growth

Short-term analysis shows that fossil energy consumption in lags 1, 2, and 4 has no significant effect on economic growth. Meanwhile, in lags 3 and 5, fossil energy consumption has a significant positive effect on economic growth with p-values of 0.0006 and 0.0367, respectively. This occurs due to high production costs resulting from volatile global fossil fuel prices, which affect input costs in economic sectors. In Indonesia, industrial and transportation sectors that heavily depend on fossil fuels often experience decreased economic efficiency when energy prices rise. The negative impact also reflects the loss of economic productivity caused by environmental and health damages from fossil fuel usage, such as air pollution and ecosystem degradation.

On the other hand, fossil energy in lag 3 has no significant effect on economic growth.
In the long term, fossil energy consumption has no effect on economic growth. This is due to the high dependence on fossil fuels, which increases vulnerability to global price fluctuations and hinders long-term economic stability. Additionally, pollution and climate change caused by fossil fuel combustion reduce competitiveness and economic efficiency. These findings align with the study by Chol (2020), which concluded that fossil energy consumption does not affect economic growth

CONCLUSION

Based on the results of the analysis that has been carried out using the analysis method, namely the Autoregressive Distributed Lag (ARDL) model in this study, the following conclusions can be drawn:

1. In the short run, electricity consumption negatively affects economic growth at lags 2, 4, and 5. However, in the long run, it has no significant impact, suggesting that increased electricity use has not effectively driven sustainable growth, possibly due to inefficiencies and limited renewable energy adoption.

2. CO_2 emissions have a positive short-run effect at lag 3 but no significant impact at other lags or in the long run. This indicates that while emissions may reflect short-term economic activity, they do not support long-term growth, highlighting the unsustainability of pollution-driven economies.
3. Fossil energy shows a positive short-run effect at lags 3 and 5 but is insignificant in the long run. This suggests fossil energy contributes to growth temporarily but lacks long-term benefits without green policies and technological innovation..
4. In the long run, electricity consumption, CO_2 emissions, and fossil energy have no significant impact on Indonesia's economic growth, emphasizing the need for a shift toward sustainable and cleaner energy sources to support long-term development.

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