

The Causality Between Energy Consumption and Carbon Emission in Indonesia

Efi Lismiyah^{1*}, Marselina¹, Arvinia Ratih Taher¹, Toto Gunarto¹, Neli Aida¹

Afiliation Universitas Lampung¹

Email efilismiyah@gmail.com*

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ABSTRACT

Energy as one part of the source of energy has a very important role as a pioneer of economic development in the activities of creation, distribution, and consumption. This research aims to identify the causes between energy consumption and carbon dioxide emissions in Indonesia. The type of research used is a quantitative research type which is analyzed using multivariate. The research results show that there is a relationship that is strong and 2-way proves that there is an increase in energy consumption which causes an increase in carbon dioxide emissions or other words an increase in energy consumption so that there is an increase in carbon dioxide emissions due to the large consumption of fossil fuels and thus an increase in carbon dioxide emissions will also be large considering that consuming fossil fuels can increase the increase in carbon dioxide emissions to a large extent. The research suggests the government needs to encourage energy efficiency through carrying out accelerated development of New Renewable Energy apart from that the government is starting to implement the use of environmentally friendly and renewable energy and improve public transportation facilities.

Keywords: Energy Consumption, Carbon Emissions, Error Correction Model

JEL Classification: E21, O14, Q74

INTRODUCTION

In recent decades, the issue of climate change has become one of the greatest environmental challenges faced by the world. The international community is increasingly realizing the importance of limiting CO₂ emissions and switching to clean energy sources to reduce the negative impacts of climate change (United Nations, 1998). However, on the other hand, sustainable economic growth is still a priority for many countries in efforts to improve social welfare and reduce poverty (Djulius et al., 2022; Mensah, 2019; Safitri et al., 2023). Climate change is becoming an increasingly urgent and complex environmental issue in Indonesia. This region is vulnerable to significant climate change, such as rising temperatures, changes in rain patterns and rising sea levels. High CO₂ emissions can worsen this condition and have a negative impact on sectors such as agriculture, fisheries and infrastructure, as well as threatening economic sustainability and social welfare (Fauzi, 2017). In recent years, the government has made efforts to reduce CO₂ emissions through clean energy policies, renewable energy development and energy efficiency. However, sustainable economic growth remains a priority in the region to overcome poverty, create jobs and improve prosperity (UNDP and partners, 2015). Efforts to reduce CO₂ emissions and switch to cleaner energy sources are important steps in addressing global climate change. However, along with that, the Government of the Republic of Indonesia must also consider sustainable economic growth in order to be able to answer the social and economic needs of the community (Pasaribu et al., 2023; Rostiana et al., 2022).

The increase in energy consumption in Indonesia also has an impact on increasing greenhouse gas emissions, especially carbon dioxide (CO₂) emissions, both in Indonesia and Southeast Asia. This occurs generally due to economic activities that are not environmentally friendly. According to Febriyastuti (2022), OECD (Organization for Economic Cooperation and Development) and ASEAN are thought to be able to contribute to the level of increase in global carbon dioxide (CO₂) emissions in 2030 (Febriyastuti Widyawati et al., 2021). This explanation is in accordance with the explanation of Sodik Dwi Purnomo, et al (2023) that as the number of industries increases every year, energy needs also increase. Energy is needed to carry out economic activities in Indonesia, both in consumption and production activities in various economic sectors. As a natural resource, energy needs to be utilized as efficiently as possible for the welfare of society and needs to be managed with policies that comply with the principles of sustainable development (Dwi et al., 2019).

Omar Muhammad Alkasasbeh, et al (2023) in his research explained that CO₂ emissions in Middle Eastern countries appear to be high compared to other countries and these high CO₂ emissions result in poor energy consumption (Osman et al., 2023). This study shows that the application of environmentally friendly technology will provide an effective solution. The research area consists of twelve countries. Saudi Arabia is the largest oil exporter and Iran is the largest natural gas exporter, where primary energy consumption in the Middle East region was recorded at around 37 exajoules and reached its peak in 2019 (37.7 exajoules). Khan's (2020) research results

also show that between energy use, economic growth and CO2 emissions in Pakistan (1965-2015) that economic growth has a positive effect on CO2 emissions in Pakistan for both observation periods (Acheampong, 2018).

METHOD

This research uses a quantitative method, choosing this method to explain a situation to be researched with the support of a literature study so as to further strengthen the researcher's analysis in making a conclusion. The quantitative research results obtained from the calculation of research variable indicators were then presented in writing by the author (Manik et al., 2023; Setiawan et al., 2021).

The operational definitions of variables in this model are as follows. Energy consumption in this study is energy use which refers to primary energy, namely energy before transformation into energy for final use (such as gasoline for transportation) in per capita energy use. The energy consumption variable indicator used is data *Energy Use per Person* (energy use per person) in Indonesia. The units of energy use in this research use units *kilowatt-jam* (kWh) is equivalent to 3.6 million Joules or 3.6 Megajoules per Capita (*World Bank Open Data*, 2023).

Carbon dioxide emissions are gases released from the combustion of carbon-containing compounds, or the release of carbon into the earth's atmosphere. The CO2 emissions variable indicator in this study uses total annual production-based carbon dioxide emissions data, excluding land use changes, and is measured in tonnes per person. It is based on territorial emissions, which does not take into account emissions inherent in traded goods (Our World in Data, 2023). The unit used to measure carbon dioxide emissions is metric tons or metric tons (MT) per capita. A metric ton is a unit equivalent to 1,000 kilograms or 1 megagram (Mg). Calculation of emission levels originating from combustion in the industrial, transportation, building and other combustion emissions sectors (Our World in Data, 2023). Carbon dioxide gas emission levels are divided into five categories, as follows:

Table 1. Carbon Dioxide Emission Levels

CO2 Emission Level (Metric Tons Per Capita)
First Class 0 – 7.42 tonnes/capita
Second Class 7.42 – 14.84 tonnes/capita
Third Class 14.84 – 22.25 tonnes/capita
Fourth Class 22.25 -29.67 tons/capita
Fifth Class 29.68 -37.09 tons/capita

Source: *World Bank*, 2023 (data processed)

The data source in this research uses timeseries data for 41 years during the period 1980 – 2021 in Indonesia. The data source was obtained from the site *World Bank Development Indicators* and *Our World in Data*, form *Gross Domestic Product* per capita Indonesia as a representation of economic growth in Indonesia, and data on the level of energy consumption and carbon dioxide emissions in Indonesia during

the period 1980 to 2021.

Data analysis in this research uses *Granger Causality*, causality test *granger* is the most popular method. This test can indicate whether a variable has a two-way relationship or only one direction. The Granger Causality Test is used to see the direction of the relationship between the observed variables

RESULT

The root test (root test) aims to determine whether there is stationarity in the timeseries information. Stagnant information is information that has consistent generality, version and covariance over time. If information that is not stagnant is used in a regression meeting, it can give rise to illegal regression (spurious regression) which causes errors in understanding the results submitted. In this research, the method used for stationarity experiments is Augment-Dickey Fuller (ADF). If the probability is below $\alpha=1\%$, $\alpha=5\%$ and $\alpha=10\%$ then the information has no root cause the information is stagnant, conversely if the probability is greater than $\alpha=1\%$, $\alpha=5\%$ and $\alpha=10\%$ until the information has a root the result not stagnant.

Table 2. Augment-Dickey Fuller (ADF) Calculation Results at the First Difference Level

Variabel	Level	Probabilitas
LKE	1 st difference	0.0001
LCO2	1 st difference	0.0000

Source: Data Processed by Researchers, 2023

Based on the ADF test, it is concluded that the probability value at the alpha level is smaller than 5%, so the energy consumption and carbon dioxide (CO₂) emissions variables have a first difference and are suitable for use in VAR or VECM analysis.

Tabel 3. Test Results Lag Optimum

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-72.74291	NA	0.012042	4.094211	4.224826	4.140259
1	29.49021	182.3618*	7.82e-05*	-0.945417*	-0.422957*	-0.761225*
2	35.09313	9.085817	9.50e-05	-0.761791	0.152514	-0.439456
3	39.34357	6.203347	0.000126	-0.505058	0.801092	-0.044579
4	48.31482	11.63837	0.000133	-0.503504	1.194491	0.095119
5	52.28217	4.503475	0.000191	-0.231469	1.858371	0.505298

Source: Data Processed by Researchers, 2023

Based on the results of this test, it proves that the lag observed is from the LR, FPE, AIC, SC, HQ numbers which have the lowest numbers, so it can be concluded that the lowest number is in the AIC column for lag 3. Therefore, lag 3 is selected as the lag. peak and is used in all subsequent levels of VAR analysis.

Cointegration experiments are used to examine the existence of long-time equilibration along with elasticity in the form. In cointegration testing, whether or not

there is a long-time balance along with elasticity is identified by equating the estimated tracestatistic number and maximum eigenvalue with the critical number.

If the trace statistic value and maximum eigenvalue are greater than the critical value at asignificance level of 0.05 or the probability value is smaller than the significance level of 0.05, this means that cointegration is involved. One approach that can be used in cointegration experiments is to use the Johansen cointegration experiment. The followingare the results of the cointegration test:

Tabel 4 Cointegration Test Calculation Results

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.423093	39.02944	29.79707	0.0033
At most 1 *	0.212238	17.02644	15.49471	0.0292
At most 2 *	0.170641	7.484087	3.841466	0.0062

Source: Data Processed by Researchers, 2023

Based on the results of the cointegration test, it can be concluded that the Trace Statisticsvalue is greater than the critical value at the 5% significance level, indicating that there isat least one equation experiencing cointegration in the system. This indicates that there is a long-term or cointegrated relationship between the three variables, namely energy consumption and carbon dioxide (CO₂) emissions. This research can apply VECM analysis.

Stability in the Vector Autoregression (VAR) model is important because it can help ensure that predictions and analysis of the impact of shocks on economic variables remainconsistent and reliable in the long term. This enables better decision making in economicplanning and policy. Stability requires that the eigenvalues of the dynamic matrix remainwithin the unit circle or less than 1 (M. Julian Tama, tt). Researchers have calculated the eigenvalues, and they were all found to fall within the circle we encounter in the image below:

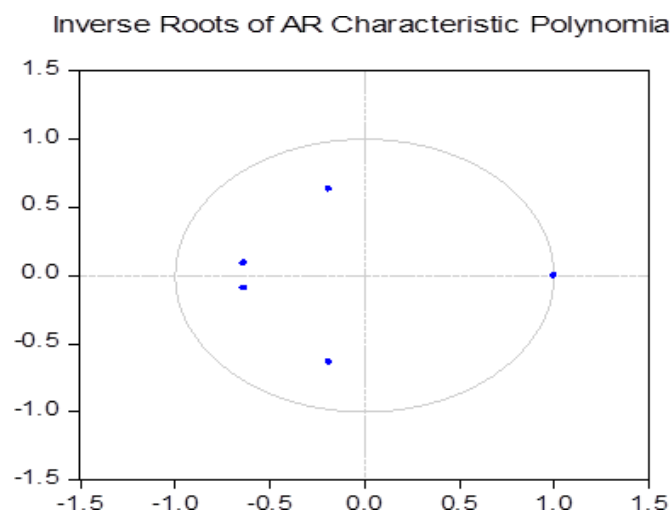


Figure 1. Stability Test for VAR Model

Based on the painting of the roundabout above, it can be seen that the point does

not come out of the roundabout, so the VAR estimate is considered normal even though there is one point that is exactly on the circle line, but the other three points are still inside the circle.

To see whether these variables have a relationship, you need to look at the t- statistic number which shows a value greater than the t-table number, so that in this research the t-table number is 1,685, and the results obtained are estimated as follows:

Table 5. Long Term VECM Test Results

Cointegrating Eq:	CointEq1
D(LKE(-1))	19.98657 (15.7867) [1.26604]
D(LCO2(-1))	-26.54263 (7.36231) [-3.60520]
C	0.379646

Source: Data Processed by Researchers, 2023

The elastic significance experiment was tried using the method of equating the statistical number of results estimated by VECM with the t-table number of 1.685 at a significance level of 5%, the results were obtained from the statistical table. Based on the results in the table, it shows that there is no long-term relationship between lag 1 of the energy consumption variable and the carbon dioxide (CO₂) emission variable.

Table 6. Long Term VECM Test Results

Error Correction	D(LKE,2)	D(LCO2,2)
CointEq1	0.003289 (0.00234) [1.40581]	0.029272 (0.00480) [6.10190]
D(LKE(-1),2)	-0.588426 (0.18034) [-3.26285]	-0.588694 (0.36979) [-1.59197]
D(LCO2(-1),2)	0.076518 (0.06323) [1.21022]	-0.198077 (0.12965) [-1.52783]
C	-0.001091 (0.00686) [-0.15905]	-0.003945 (0.01407) [-0.28042]
R-squared	0.357547	0.625826
Adj. R-squared	0.281965	0.581806
F-statistic	4.730544	14.21673

Source: Data Processed by Researchers, 2023

Based on the table above, it shows that at lag 2 the carbon dioxide (CO₂) emission variable does not have a short-term relationship with energy consumption in Indonesia. Impulse Response Function (IRF) is needed to understand what impact an elastic shock has on the elastic itself and other variables in the system. IRF describes how to estimate the impact of an elastic shock on other variables so that it can be known how long the

impact of the shock or fluctuation of an elastic thing on other variables will be experienced, and which elastic will give the greatest response to the shock, (M. Julian Tama, tt).

The following is a display of the Impulse Response Function (IRF) graph, as below:

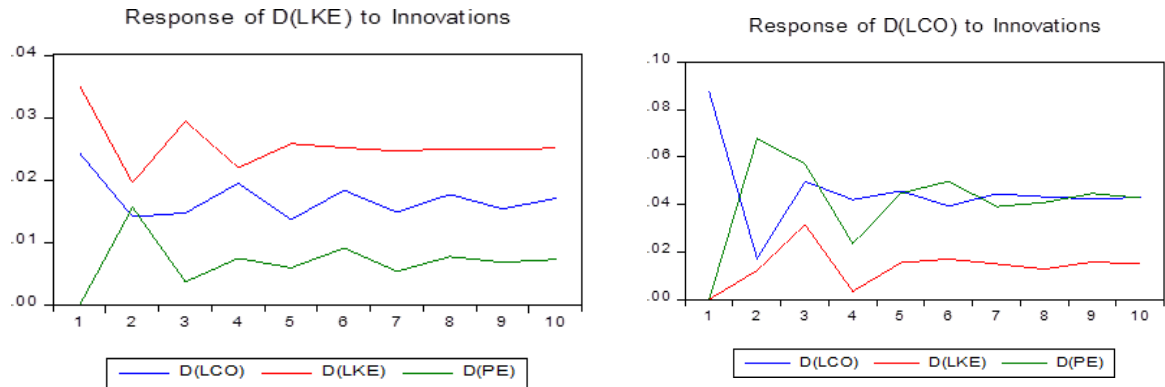
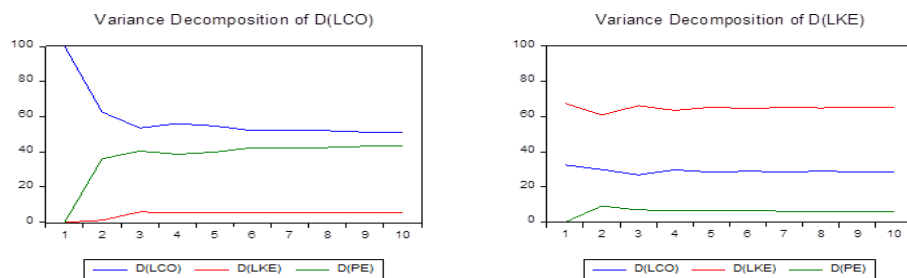


Figure 2. Impulse Response Function (IRF) Graph

The results of the Impulse Response Function (IRF) analysis with economic growth as a response show that in the next 42 years, the highest response will be carbon dioxide (CO₂) emissions in response to energy consumption, and this is anticipated to remain stable at the 6th standard deviation level. Impulse Response Function (IRF) analysis with carbon dioxide (CO₂) emissions as a response shows that the highest response is economic growth in response to an increase in carbon dioxide (CO₂) emissions, stable at the 7th standard deviation level.

Variance Decomposition (VD) is a part of VECM analysis which aims to support findings from previous analysis. VD provides an estimate of the extent to which an elastic functions in creating changes in the elastic itself and other elastics in the future, measured in the form of a percentage. This allows us to determine which elastics are expected to provide the most participation to a particular elastic, (M. Julian Tama, n.d.). Meanwhile, if you look at the graph, the results of the Variance Decomposition



(VD) test are as follows:

Figure 3. Variance Decomposition (VD) Graph

The picture above shows that the movement of the graph in Variance Decomposition (VD) will mutually influence the contribution between variables per year. The Variance Decomposition (VD) results in the image above for the next 10 years provide a different picture, but each variable contributes to each other. Economic growth is influenced by

itself with a contribution of 74.75% which means it shows internal stability in economic growth in the next 10 years. Economic growth contributed greatly to 66.20% on energy consumption. Then economic growth also makes a contribution of 50.95% of carbon dioxide (CO₂) emissions in Indonesia.

The quality test is carried out to determine the reciprocal relationship between variables or it can also be interpreted as whether the variable can be a dependent or independent variable. There are various methods for conducting causality tests. One method used is the Granger causality test. To see whether these variables have influence or causality, that is by looking at the f-statistic value which shows a number greater than the t-table value. In this study, the t-table value was 1.685, the following are the results of the Granger causality test:

Table 7. Granger Causality Test Results

Null Hypothesis	Prob.	Conclusion
LKE does not Granger Cause LCO ₂	0.0049	There is a relationship between energy consumption and carbon dioxide (CO ₂) emissions
LCO ₂ does not Granger Cause LKE	0.0303	There is a relationship between carbon dioxide (CO ₂) emissions with energy consumption

Source: Data Processed by Researchers, 2023

The results of the causal experiment between energy consumption and carbon dioxide (CO₂) emissions prove that there is an important relationship, there is a strong relationship and two directions prove that there is an increase in energy consumption which causes an increase in carbon dioxide (CO₂) emissions or in other words an increase in energy consumption to There is an increase in carbon dioxide (CO₂) emissions because when consuming large amounts of fossil fuels, the increase in carbon dioxide (CO₂) emissions will also be large considering that consuming fossil fuels can increase the increase in carbon dioxide (CO₂) emissions to a large extent.

DISCUSSION

Based on the calculation results between energy consumption and carbon dioxide emissions and energy consumption which shows that there is a significant two-way relationship, this is in accordance with the research hypothesis. The significant relationship between energy consumption and carbon dioxide emissions shows that an increase in carbon dioxide emissions will be the main trigger for global warming, starting from the dependence of several countries on non-environmentally friendly transportation, including Indonesia, which has not yet massively used environmentally friendly energy.

One of the causes is the high cost of environmentally friendly energy such as solar panels, so the use of fossil fuels such as petroleum and coal is still the government's choice for producing electricity. This is the cause of increasing carbon dioxide emissions which also reflects high energy consumption in Indonesia (Afrina et al.,

2015).

The results of this research are supported by research by Mahmoud Salari et al (2021), explaining that there is a relationship in both the long and short term between various types of energy consumption and CO₂ emissions at the state level (Buanawaty & Faisal Hastiadi, 2017). Therefore, the main energy source compared to non-renewable energy will increase the growth process and improve environmental quality. Arista and Amar (2019), in their research also explained that there is causality between the economy and CO₂ emissions, namely CO₂ emissions that influence economic growth and economic growth that affects CO₂ emissions. There is a relationship because CO₂ emissions have occurred, where forestry or plants also store CO₂ emissions, as well as the sea which also causes CO₂ emissions (Stern, 2004). Apart from this, disasters such as forest fires can also cause an increase in CO₂ emissions. With high total CO₂ emissions, it can influence countries or individuals in determining how much energy they consume in total. Apart from that, energy consumption can also affect CO₂ emissions because when fossil fuel consumption is high, CO₂ emissions will also be high considering that fossil fuel consumption can increase CO₂ emissions to high levels.

The existence of a strong and two-way relationship shows that there is an increase in energy consumption which causes an increase in carbon dioxide emissions, or in other words, if there is an increase in energy consumption, there is an increase in carbon dioxide emissions, because when fossil fuel consumption is high, carbon dioxide emissions increase. The consumption of fossil fuels also increases which can increase emissions to high levels. This explanation is in line with Jing Li, et al (2023), in his research explaining that in the short and long term energy consumption in developed countries has a positive impact on CO₂ emissions, while in developing countries energy consumption in both the short and long term has an influence. which is beneficial to CO₂ emissions (Chen et al., 2023).

Kahia et al. (2019), argue that economic growth, the level of total carbon dioxide emissions and the level of renewable energy consumption in 12 countries in the Middle East. Their study has been carried out over the period 1980 - 2012 and the PVAR model has been applied to prove "bidirectional causality". According to Omri A. (2013), his research also tested the causality between energy consumption and emissions in 14 Middle East North America (MENA) countries in the 1990-2011 period and the result was that energy consumption influenced CO₂ emissions with a one-way relationship.

Rasyid Latief and Lin Lefen (2019), in their research explained the existence of a causal relationship between the use of biomass energy reducing CO₂ emissions and increasing environmental sustainability in Pakistan during the period 1990 – 2017. Meanwhile, Soytaş and Sari (2009), investigated the causal relationship using tests *Granger* between emissions and energy consumption in Türkiye, the result is that there is a unidirectional relationship from emissions to energy consumption. Similar results were also obtained from research by Dwi Resti Pratiwi (2021), explaining that

energy use and CO₂ emissions have a strong and two-way causal relationship, where there is a two-way relationship from energy consumption to CO₂ emissions (Budiwan et al., 2020).

CONCLUSION

There is a two-way causal relationship between energy consumption and emissions carbon dioxide in Indonesia during the period 1980 – 2021. This means that the higher the energy consumption, the higher the carbon dioxide emissions because there is a strong and two-way relationship showing an increase in energy consumption which causes an increase in carbon dioxide emissions or in other words, an increase in energy consumption means there is The increase in carbon dioxide emissions is due to the high consumption of fossil fuels and the increase in carbon dioxide emissions will also be high considering that the consumption of fossil fuels can increase the increase in carbon dioxide emissions to high levels.

Based on the results of the discussion and conclusions presented above, the author will outline several suggestions, namely as follows. The government needs to establish and implement policies that encourage energy efficiency so that energy intensity is lower implementing accelerated development of New Renewable Energy with a few steps: *First*, Through the development of renewable energy infrastructure, the government encourages the development of renewable energy infrastructure such as solar power plants, wind power plants and hydroelectric power plants. Infrastructure development helps increase community access to clean and sustainable renewable energy. *Second*, reducing the cost of renewable energy, efforts to reduce the cost of renewable energy so that it is more affordable for the community, which can be done through subsidy policies, incentives and the development of the latest technology. *Third*, public education and awareness, by increasing public knowledge, society will be more open to adopting renewable energy technology and applying it in everyday life.

Regarding high emissions due to energy use, a low-carbon technological transformation is needed which aims to reduce emissions and sustain economic growth. This not only keeps the economy green, but also preserves the environment for future generations. Therefore, the government needs to design and start implementing the use of environmentally friendly and renewable energy, especially for electricity generation. Improving public transportation facilities and also updating laws for externalities caused by industrialization, so as to reduce the amount of carbon dioxide emissions released into the earth's atmosphere.

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