Efficient Vol 8 (1) (2025): 112-121 DOI: https://doi.org/10.15294/rmkbhg65

EFFICIENT

Indonesian Journal of Development Economics

https://journal.unnes.ac.id/sju/index.php/efficient

The Relevance of Energy Consumption and Economic Growth Indicators to Anthropogenic Disasters

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Permalink/DOI: https://doi.org/10.15294/rmkbhg65

Submitted: July 2024; Revised: October 2024; Accepted: January 2025

Abstract

This study aims to analyze the effects of GDP per capita, Foreign Direct Investment (FDI), primary energy consumption per capita, and electricity consumption per capita on carbon emissions in Indonesia, both in the short and long term, during the period from 1974 to 2022. The data for this study were obtained from the World Bank, Enerdata, the Ministry of Energy and Mineral Resources, and Our World in Data. The Error Correction Model (ECM) was employed to address empirical questions regarding the long-term and short-term relationships among the research variables. The findings indicate that GDP per capita has a positive but not significant impact on carbon emissions in both the short and long term. Moreover, FDI shows a positive and significant relationship with carbon emissions in the long term but does not exhibit a significant relationship in the short term. These results also highlight the negative impact of FDI, proving the occurrence of the pollution haven hypothesis in Indonesia. On the other hand, both primary energy consumption per capita and electricity consumption per capita show a positive and significant correlation with carbon emissions in both the short and long term.

Keywords: GDP, Foreign Direct Investment, Energy, Electricity, Consumption, Carbon Dioxide Emissions

How to Cite: The Relevance of Energy Consumption and Economic Growth Indicators to Anthropogenic Disasters. (2025). Efficient: Indonesian Journal of Development Economics, 8(1), 112-121. https://doi.org/10.15294/rmkbhg65

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INTRODUCTION

Recently, global warming has become a major international concern, marked by the rise in the Earth's average surface temperature, leading to continuous global climate change. Research by the Intergovernmental Panel on Climate Change (IPCC) indicates that global warming over the last 150 years has triggered

various natural anomalies, such as increases in air and ocean temperatures, ice melting, and rising sea levels. These phenomena suggest climate changes that could lead to environmental degradation.

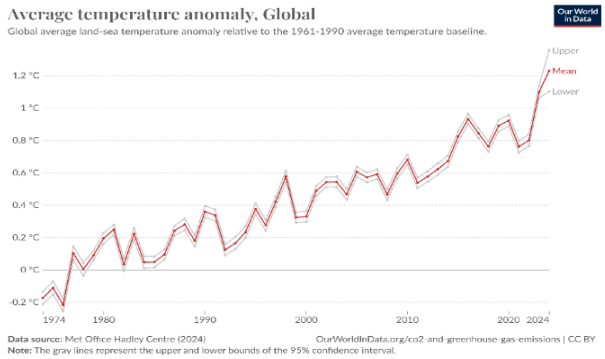

Figure 1. Average temperature anomaly, global
Source: Our world in data, 2024

Evidence of environmental degradation is apparent through climate anomalies that have led to a steady increase in global average temperatures each year. The data illustrates a consistent temperature rise, reflecting the impact of industrialization that disregards ecological balance, resulting in CO2 emissions that drive the greenhouse effect (GHG) and global warming. GHGs are caused by various gases, with CO2 being the largest contributor, accounting for approximately 76.70% of all GHG components.

Indonesia, as a developing country, faces significant challenges from climate change. According to data from the World Research Institute (WRI), in 2018, Indonesia ranked eighth among the world's largest emitters, contributing around 2% of the total global emissions. By 2022, Indonesia had risen to sixth place, with emissions totaling 729 million tons. This situation highlights the deteriorating environmental quality in Indonesia, as reflected by the substantial carbon dioxide emissions produced by the country from 1974 to 2022.

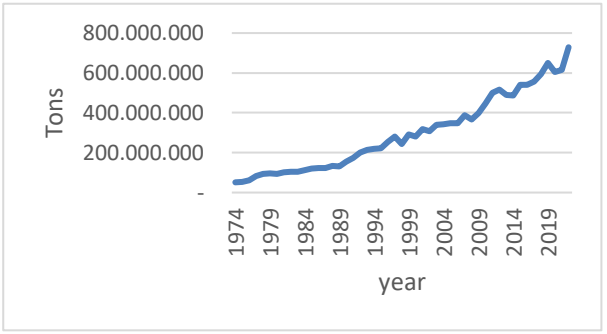

Figure 2. Carbon dioxide emissions
Source: Our world in data, 2024

From 1974 to 2022, carbon dioxide (CO_2) emissions in Indonesia consistently and significantly increased each year, with the trend notably accelerating after 2000. The largest surge occurred between 2020 and 2022, exceeding 700 million tons of CO_2 by 2022. This rise in CO_2 emissions thickens the atmospheric layer, exacerbating the greenhouse effect and driving global warming, which is expected to increase Earth's temperature by 1.1 to 5 degrees Celsius in the next 50 to 100 years.

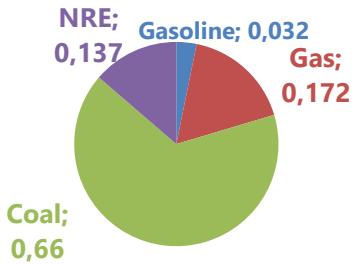

Figure 3. Dominance of Electricity Production
Source: Kementerian ESDM, 2024

Human activities, particularly the use of non-renewable energy sources, are the primary drivers of this CO_2 increase, which has been recognized as the leading cause of global

warming. The IPCC's 2002 report also noted that human activities could cause global temperatures to rise by 1.4 to 5.8°C this century. Most human activities, including economic ones, still heavily rely on fossil fuels, which disrupt the ecosystem balance and are not aligned with sustainable development goals, especially as a primary source in electricity production.

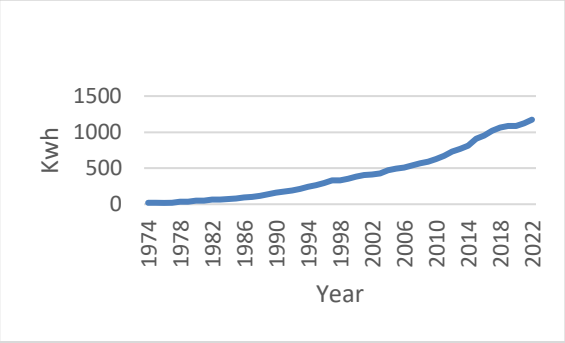

Figure 4. Per capita electricity consumption
Source: Our world in data, 2024

Consumption of fossil fuels as the main source of electricity in Indonesia remains dominant, as shown in figure 3, where most electrical energy is generated from fossil fuels. This electricity production process emits CO_2, primarily due to the combustion of fossil fuels. As the population grows and the economic sector expands, electricity consumption in Indonesia continues to rise annually, still heavily dependent on non-renewable energy sources like coal, increasing the risk of CO_2 emissions surges.

Figure 4 also shows an increase in per capita electricity consumption.The growth in electricity consumption in Indonesia from 1974 to 2022, as indicated by World Bank data (see figure 4), suggests negative externalities in the form of increased carbon dioxide (CO_2) emissions, which adversely affect environmental quality. Electricity consumption, mostly still derived from fossil fuels, contributes to rising CO_2 emissions, which worsen as electricity demand from various sectors increases.

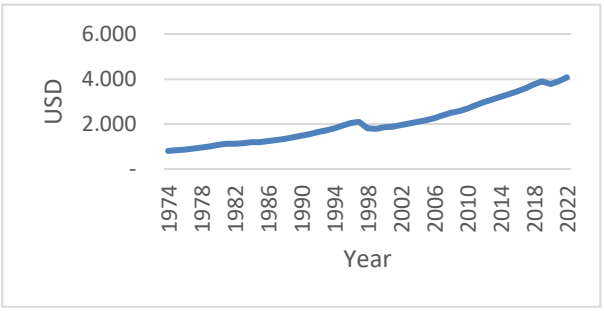

Figure 5. GDP Per capita
Source: Our world in data, 2024

Economic growth, reflected in rising GDP, requires more resources and energy, which also results in more waste in the form of CO_2 emissions, thereby exacerbating unavoidable environmental degradation (Aida, Hermawan, and Ciptawaty, 2022).

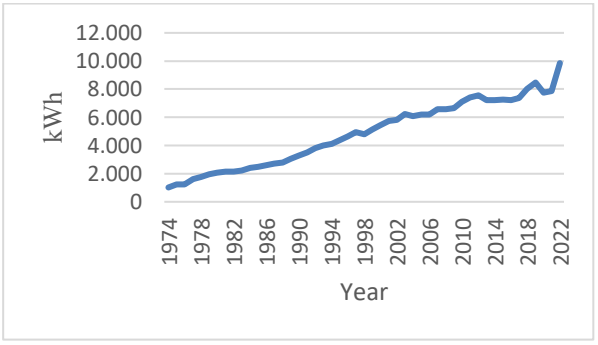

Figure 6. Primary Energy Consumption
Source: Our world in data, 2024

Figure 5 shows that economic growth from 1974 to 2022 aligns with the increase in carbon dioxide emissions.The relationship between environmental degradation and economic growth is often explained through the Environmental Kuznets Curve (EKC). According to Kuznets (1955), income distribution tends to

become more unequal during the early stages of development but improves after reaching a certain point.

This indicates that there is a certain level of economic growth that, once achieved, can begin to reduce the environmental impact caused by the early stages of development (Kizilkaya, 2017). Based on this view, the EKC hypothesis suggests that initially, economic development in countries leads to environmental degradation, but once per capita income reaches a certain level, this process will reverse, leading to environmental improvement (Saudi et al., 2017).

Primary energy consumption is one of the main drivers of Indonesia's economic growth. Increased energy consumption, especially from non-renewable sources, drives up carbon dioxide emissions (Ozturk and Acaravci, 2010). The growth in energy consumption in Indonesia is dominated by oil and natural gas, which account for more than 40 percent.

Indonesia is the largest energy consumer in Southeast Asia and ranks fifth in the Asia-Pacific region after China, India, Japan, and South Korea (BPPT, 2018). Several studies have shown a relationship between energy consumption and increased carbon dioxide emissions, as found by Osobajo et al. (2020), which demonstrated a long-term relationship between economic growth, energy consumption, and carbon dioxide emissions.

Based on figure 6, it is evident that primary energy consumption in Indonesia has consistently increased due to high energy demand. Data from 1974 to 2022 indicates a strong correlation between per capita primary energy consumption and CO_2 emissions. As per capita energy consumption rose from 1,021 kWh in 1974 to 9,854 kWh in 2022, CO_2 emissions surged from 51.2 million tons to 728.8 million tons.

The increase in energy consumption, particularly from fossil fuels, is the primary cause of rising CO_2 emissions. Additionally, foreign direct investment (FDI) has also contributed to the increase in emissions, even though FDI is a crucial source of economic growth for developing countries, as noted by Soekro and Widodo (2015). World Bank data from 2022 also shows an annual increase in FDI flows to Indonesia, as seen in figure 7.

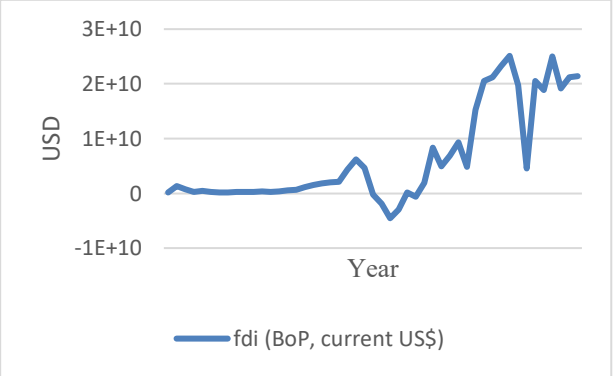

Figure 7. Foreign Direct Investment
Source: Our world in data, 2024

Based on figure 7, the inflow of FDI into Indonesia has shown a consistent upward trend, particularly since the 2000s. Foreign Direct Investment (FDI) can stimulate economic growth in the host country, but it may also lead to negative impacts, such as environmental degradation, if not accompanied by modern or environmentally friendly technology, a concept known as the Pollution Haven Hypothesis.

This hypothesis posits that foreign companies relocate polluting industries to countries with more lenient regulations, which can increase emissions in those countries (Mehdi & Taleghani, 2022). FDI may serve as a means of outsourcing "dirty industries,"

especially to less developed countries with weak environmental regulations, creating so-called "pollution havens." This finding aligns with research by Ren et al. (2014), which indicates that FDI increases CO_2 emissions in China. There is also a contrasting view that FDI can reduce CO_2 emissions, as suggested by studies by Tang and Tan (2015) and Zhang and Zhou (2016), which found that FDI has a significant negative effect on CO_2 emissions, actually helping to reduce them.

Several studies have shown inconsistent results regarding the relationship between energy consumption and the aforementioned economic indicators and CO_2 emissions. For example, Khan et al. (2019) found that economic growth has a significant negative impact on CO_2, while Shahbaz et al. (2013) found a significant positive impact. Additionally, Prasetyawati (2019) demonstrated that economic growth has a negative relationship with carbon emissions in the short term but a positive one in the long term. FDI remains the largest contributor to carbon emissions in Indonesia.

The increasing complexity of environmental issues has driven global awareness through various initiatives, such as the 1992 Rio Earth Summit, which involved 172 countries and resulted in Agenda 21, a global action program for sustainable development agreed upon by 178 countries, including Indonesia (Fadli, 2022).

Additionally, the Kyoto Protocol (1997), Bali Action Plan (2007), and Paris Agreement (2015) have also been significant steps forward. COP-13 in Bali produced the Bali Action Plan, which focused on reducing emissions and deforestation in developing countries, while the Paris Agreement strengthened global efforts to tackle climate change and reduce emissions (Yuliartini and Suwanto, 2022). Indonesia has implemented a Net Zero Emission strategy aiming to reduce greenhouse gas emissions to near zero, so that any remaining emissions can be absorbed by nature (Kementerian Koordinator Bidang Perekonomian Indonesia, 2022).

However, policies to address challenges such as dependence on fossil fuels and low public awareness of environmental quality have not yet yielded optimal results. Despite Indonesia's GDP per capita rising from 1974 to 2022, CO_2 emissions remain high, indicating a gap between theory and practice. Energy consumption and the economic indicators mentioned above have been shown to influence the increase in CO_2 emissions, which is not aligned with the principles of sustainable development. This gap makes it difficult to realize the concept of sustainable development in Indonesia, which

requires environmental preservation as one of its main pillars. Therefore, further analysis is needed to understand the contribution of each factor to CO_2 emissions. Given the inconsistency in research findings related to the Environmental Kuznets Curve and the pollution haven hypothesis, as well as the differences in the impact of factors contributing to CO_2 emissions in Indonesia, further empirical research is necessary to evaluate the accuracy of these theories and the influence of related variables in Indonesia.

RESEARCH METHODS

The approach used in this research is based on a quantitative method within an associative research type. Quantitative methods involve the use of numerical data analyzed through statistical methods. The associative

research type applied here explores the relationships between two or more variables that will be tested. The data analysis technique for this research utilizes the Error Correction Model (ECM). ECM is an econometric analysis method used to observe and analyze the long-term and short-term impacts of each independent variable on the dependent variable.

The application of the ECM method aligns with the research objective, which is to analyze the short-term and long-term effects of the independent variables on the dependent variable. To implement the ECM regression in this research, the software Eviews 12 is used to manage the available data. The equation model for the Error Correction Model (ECM) in the long term is as follows:

$$CO2_t = \alpha_0 + \alpha_1 GDP_t + \alpha_2 FDI_t + \alpha_3 KEL_t + \alpha_4 KEP\_KAP_t + \varepsilon_{it}$$

The equation model for the Error Correction Model (ECM) in the short term is as follows:

$$CO2_t = \alpha + \beta_1 GDP_t + \beta_2 FDI_t + \beta_3 KEL_t + \beta_4 KEP\_KAP_t + \beta_5 ECT_t + \varepsilon_t$$

In the long-term analysis, the variables used include carbon dioxide emissions (CO_2), Gross Domestic Product (GDP) per capita, primary energy consumption per capita (KEP_KAP), foreign direct investment (FDI), and electricity consumption per capita (KEL). The regression coefficient (α) indicates the relationship between these variables and CO_2 over the 1974-2022 period, with year t referring to a specific year within this range. The error term (ε) encompasses all other factors influencing CO_2 that are not explained by the modeled variables.

In the short-term analysis, the regression coefficients (β_1, β_2, β_3) represent the impact of each independent variable on CO_2. The residual (ε) accounts for the unexplained error in the model, and the Error Correction Term (ECT) or (Residualt-1) represents the leftover from the previous period used to correct any imbalance in the short-term model based on past observations. The time (t) still refers to a specific year within the same period.

This research utilizes secondary data, referring to information that has already been compiled, processed, and published by specific institutions and proven accurate. The secondary data in this study consists of time-series data spanning from 1974 to 2022 in Indonesia. Data on carbon dioxide, foreign direct investment (FDI), primary energy consumption per capita, and electricity consumption per capita were obtained from the World Bank, Enerdata, the Ministry of Energy and Mineral Resources (ESDM), and Our World in Data.

The ECM method is an effective tool to address the issue of spurious regression, which occurs when regression results do not accurately reflect the actual conditions because the independent and dependent variables are not stationary. This causes the analysis results to be inaccurate since these variables do not truly influence each other. The advantage of ECM lies in its ability to analyze both the short-term and long-term effects of the variables under study. The use of ECM requires that the data must be non-stationary at the initial level and become stationary after the first difference, and there must be cointegration or a long-term effect among the variables studied.

RESULTS AND DISCUSSION

Based on the testing results, the Error Correction Model (ECM) meets the requirements and is free from classical assumption issues. The results of this ECM test can be seen in table 1.

Table 1. Shorterm ECM Test Results

Variable	Coef	T-Stats	Prob
C	-3491697	-1.280940	0.2072
D(FDI)	0.000548	1.306505	0.1985
D(GDP)	2435.906	0.080287	0.9364
D(KEP_KAP)	51869.87	9.287609	0.0000
D(KLP)	300508.6	2.925923	0.0055
ECT(-1)	-0.66986	-4.49982	0.0001
R-Squared		0.833503	
Adjusted R-squared		0.813682	
F-Statistic		42.05143	
Prob (F-statistic)		0.000000	

Source: Data processed, 2024

Based on the results of the short-term Error Correction Model in table 1, it can be observed that ECT(-1) has a value of -0.669868 with a probability of 0.0001, which is less than 0.05 (the significance level used), indicating that the ECT(-1) value is negative and significant. The value of ECT(-1) also shows that, at the used significance level of 5 percent, short-term equilibrium fluctuations will be corrected to the long term with a decrease of 0.6700%. The negative and statistically significant coefficient of ECT suggests that the ECM model specification applied in this study is appropriate (Gujarati, 2014).

Additionally, the short-term Error Correction Model results show that the variable D(KEP_KAP) has a positive effect with a probability value of 0.0000 and a coefficient of 51869.87, which means that an increase in primary energy usage by 1 kilowatt-hour (kWh) will result in an increase in carbon dioxide emissions by 51869.87 tons, assuming all other factors remain constant.

The next variable, D(KLP), also has a positive effect with a probability value of 0.0055 and a coefficient of 300508.6, indicating that an increase in electricity consumption by 1 kilowatt-hour (kWh) will raise carbon dioxide emissions by 300508.6 tons, assuming all other factors remain constant. The constant term in the short-term ECM estimation for this study is -3491697, which means that if all independent variables remain constant, carbon dioxide emissions, as the dependent variable, will decrease by 3,491,697 tons.

Table 2. Longterm ECM Test Results

Variable	Coef	T-Stats	Prob
C	13267341	0.752332	0.4559
FDI	0.001459	3.114913	0.0032
GDP	961.6146	0.050486	0.9600
KEP_KAP	30984.92	10.86451	0.0000
KLP	293441.1	6.647628	0.0000
R-Squared		0.995403	
Adjusted R-squared		0.994985	
F-Statistic		2381.908	
Prob (F-statistic)		0.000000	

Source: Data processed, 2024

Based on the results from the long-term Error Correction Model estimation in table 2, the constant value is 13,267,340.8207. This means that if the independent variables in the study—GDP per capita, FDI, per capita primary energy consumption, and per capita electricity

consumption—are held constant, the dependent variable, carbon dioxide emissions, will increase by 13,267,340.8207 tons. The FDI variable has a positive effect with a probability value of 0.0032 and a coefficient of 0.001459, indicating that an increase of $1 in FDI will raise carbon dioxide emissions by 0.0015 tons, assuming all other factors remain constant.

The next variable, KEP_KAP, has a positive and significant effect with a probability value of 0.0000 and a coefficient of 30,984.92. This means that an increase of 1 kilowatt-hour (kWh) in per capita primary energy consumption will lead to an increase in carbon dioxide emissions by 30,984.92 tons, assuming all other

factors remain constant. The KLP variable also has a positive effect with a probability value of 0.0000 and a coefficient of 293,441.1, indicating that an increase of 1 kilowatt-hour (kWh) in per capita electricity consumption will result in an increase in carbon dioxide emissions by 293,441.1 tons, assuming all other factors remain constant. Lastly, the GDP variable has a probability value of 0.9600 and a coefficient of 961.6146, which indicates a positive effect but is not statistically significant.

CONCLUSION

GDP per capita has an insignificant positive effect on CO_2 emissions in both the short and long term. Meanwhile, FDI has an insignificant positive effect on CO_2 emissions in the short term but a positive and significant effect in the long term. Per capita primary energy consumption has a significant positive effect on CO_2 emissions in both the short and long term. Similarly, electricity consumption also shows a significant positive effect on CO_2 emissions in Indonesia during the period from 1974 to 2022.

To reduce carbon emissions, the government could increase carbon taxes for industries using non-renewable energy and provide fiscal incentives to companies investing in renewable energy sources such as solar, wind, and biomass. Additionally, implementing environmentally friendly technologies should be mandatory for large companies, including the use of solar panels on buildings and homes.

Stricter emission standards and routine monitoring and reporting systems are necessary to ensure industry compliance with emission limits, with severe penalties for violations. The government should also increase investment in environmentally friendly technologies and facilitate the energy transition through financial and technical support, such as low-interest loans or grants for research and development of green energy technologies.

Further research could include regulatory aspects such as corruption indices and ecological regulation indices, as good environmental regulations act as tools for reducing carbon dioxide emissions. Additionally, the synergy and integrity of stakeholders with the regulations, especially in the environmental field, are crucial and reflected in low corruption levels. Future researchers are also encouraged to extend and update the study period.

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