ANALYSIS OF ECONOMIC GROWTH AND CARBON EMISSIONS IN INDONESIA

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Abstract

The increase in greenhouse gas emissions, particularly carbon dioxide, which remains a major global energy concern, continued to rise by 0.9 percent in 2022 following the COVID-19 pandemic. Indonesia ranks sixth globally as one of the largest emitters, with coal-based industries contributing the majority of its emissions. This study employs a quantitative approach using the variables of economic growth, energy consumption, deforestation, and foreign direct investment (FDI) over the period 1990–2022. The data were obtained from the World Bank and various international and Indonesian academic publications. The results show that economic growth significantly increases carbon emissions, whereas deforestation and FDI reduce emissions; energy consumption exhibits no significant effect. Overall, the findings indicate that rising carbon emissions in Indonesia are driven by environmentally unsustainable economic expansion, consistent with the Environmental Kuznets Curve (EKC) hypothesis. This is further supported by the impulse response function and variance decomposition analyses, which highlight the positive association between economic growth and carbon emissions. Meanwhile, deforestation and FDI do not contribute to higher emissions, and the transition toward more sustainable energy consumption in Indonesia results in an insignificant impact on emission growth

Keywords: Carbon Emissions, Economic Growth, Energy Consumption, Deforestation, Foreign Direct Investment

INTRODUCTION

The environment and the economy are closely related, and many countries around the world have recognized this, with 195 countries agreeing to mitigate climate change in 2015 through the Paris Agreement. The main focus is to promote climate resilience and reduce greenhouse gas emissions, implement renewable energy, and address various economic issues that take the environment into account. Indonesia itself was among the first 55 countries to ratify the agreement (Paris Agreement, 2015). According to the latest IEA report for 2025, globally, the gas that dominates greenhouse emissions in 2024 is carbon dioxide with a percentage of 74.5 percent, followed by methane, nitrous oxide, and gas f.

Most carbon dioxide gas comes from the burning of organic materials such as coal, petroleum and natural gas, wood, and solid waste. High greenhouse gas emissions are generally caused by humans releasing gases into the air through the burning of fossil fuels. These gases then absorb solar energy and trap heat around the earth instead of releasing it into space, a phenomenon known as the greenhouse effect (Nunez, 2019).

Carbon itself is a chemical element found in gases and compounds. CO2 is the greenhouse gas most emitted by human activities in terms of the quantity released and its impact on global warming. There is a lot of confusion about using carbon emissions as the entire greenhouse gas emission. This is because carbon emissions are indeed referred to as the most important greenhouse gas, but there are still many other gases that are not widely discussed and included in many GHG emission reports (Brander & Davis, 2023).

According to a report released by JRC/IEA on greenhouse gas emissions in countries around the world for 2024, Indonesia is among the countries with the highest carbon emissions, ranking sixth after China, the United States, India, the European Union, and Russia. This increase is mainly contributed by coal, and Indonesia experienced the highest increase compared to 2023, which was almost 5%. The Indonesian government is committed to reducing GHG emissions to below 26% below business-as-usual levels by 2020. However, GHG emissions in Indonesia increased significantly between 2018 and 2022. In 2022, carbon (CO2) emissions in Indonesia were also recorded as the highest compared to other gases, accounting for 77% of all GHG emissions. Greenhouse gases mostly come from industry. It was recorded at around 86.9 % between 2018 and 2022 (Firdaus et al., 2024). This shows that productive economic activities contribute significantly to GHG emissions in Indonesia.

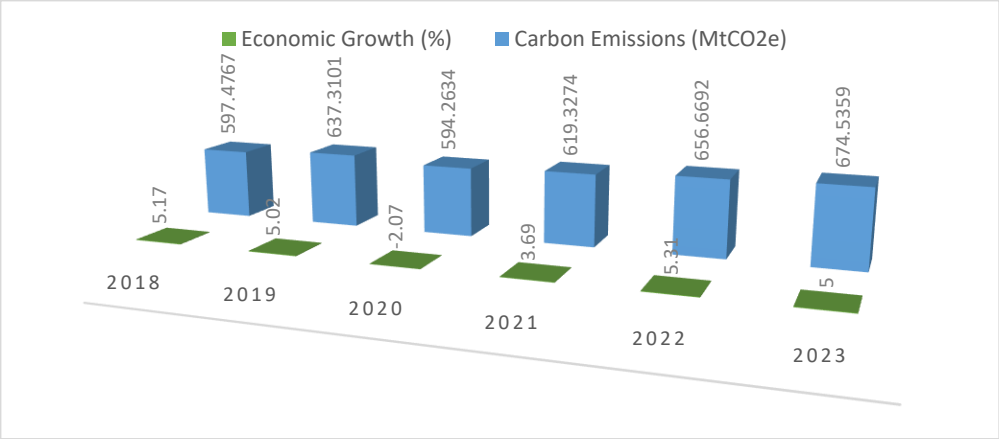

Figure 1.
Indonesia's Economic Growth and Carbon Emissions from 2018 to 2023
Source: Central Statistics Agency & World Bank

Indonesia's fluctuating economic growth from 2018 to 2023 may be due to several global issues such as pandemics, wars between countries, and the country's own political situation. Figure 1.1 shows a decline in gross domestic product growth in 2020 in line with a decline in

carbon emissions of 594.2634 Mt CO2e. GDP growth then improved in 2021, followed by an increase in emissions of 619.3274 Mt CO2e. According to Sudirman (2010), economic development is considered successful if the country's economic growth is high. Economic development is focused on spurring economic growth, although sometimes it does not take into account environmental sustainability and natural resources.

High economic growth will affect the increase in GHG emissions, supported by research findings that economic growth is positively related to GHG emissions in the United States and China, as well as research in five BRICS countries (Mu Tashim & Rudatin, 2023; Yamaka et al., 2021). However, GHG emission mitigation that reduces excessive dependence on fossil fuel consumption is also not good for economic growth (Appiah, 2018). On the other hand, economic growth has a negative and significant impact on carbon emissions because good economic performance enables the implementation of efficient and sustainable production (Zubair et al., 2020), and sustainable economic development can effectively combat global warming, as shown in a study of 27 EU countries and Turkey (Çomuk et al., 2023).

High economic growth will be followed by energy consumption demand and carbon emissions. The highest energy consumption sectors in Indonesia are the coal and palm oil industries. High consumption by the community will mutually influence one sector with another. The relationship between people living in cities and rural areas is similar to that in developed and developing countries. Developed countries with high incomes build their economies without adding to environmental problems and with a decline in energy consumption, while developing countries find it difficult to overcome the problems of energy consumption and economic growth (Aruga, 2019). In the United States, energy consumption is said to reduce GHG emissions (Yamaka et al., 2021), but this is not the case in Bangladesh, which lacks environmentally friendly technology and fuel utilization as well as economic growth (Rahman & Kashem, 2017). Similarly, energy use in Tunisia is inefficient, accompanied by environmental pressures on economic growth and a positive long-term relationship with carbon emissions (H.E & Y, 2008).

The relationship between people living in cities and rural areas is similar to that in developed and developing countries. Developed countries with high incomes build their economies without adding to environmental problems and with a decline in energy consumption, while developing countries find it difficult to address the issues of energy consumption and economic growth (Aruga, 2019). In the United States, energy consumption is said to reduce GHG emissions (Yamaka et al., 2021), but this is not the case in Bangladesh, which lacks environmentally friendly technology, fuel utilization, and economic growth (Rahman & Kashem, 2017). Similarly, energy use in Tunisia is inefficient, accompanied by environmental pressures on economic growth and a positive long-term relationship with carbon emissions (H.E & Y, 2008).

The close relationship between economic growth and energy consumption is also related to land use and the decision of other countries to invest in Indonesia. Sustainable economics also discusses deforestation. "Life on Land" focuses on protecting and restoring sustainable terrestrial ecosystems and managing forests sustainably. According to the Data Insight Centre (2022), the use of forests and land is a result of large-scale deforestation for industrial palm oil plantations, with an estimated average of 498,000 hectares of forest lost each year. In 2023, coal production exceeded the expected target of 694.5 million tons. In fact, the recorded production in December 2023 was 703.14 million tons. This supports the fact that energy consumption and demand are high and originate from China and India. Deforestation was the main activity carried out by humans from 1981 to 2000, contributing around 30 percent of CO2 emissions (Data Insight Centre, 2022).

Indonesia is known as a tropical country rich in natural resources. The main source of energy supply for domestic consumption in developing countries is forests, while agricultural

residues are an alternative source of energy supply in rural communities (Adkins et al., 2012). However, Indonesia's high rate of land conversion and deforestation is reinforced by the fact that Indonesia ranks fourth in terms of the most forest loss in the world (Weisse et ., 2024). In the field, it is necessary to reduce emissions from degradation and deforestation, reorganize sustainable forest management, and increase forest carbon availability.

In Ethiopia, forest cover has a negative relationship with economic growth, but forest cover has a positive and significant effect on energy consumption, which has a two-way and significant relationship (Woldemedhin et al., 2022). Deforestation has a positive and significant effect on carbon emissions (Gamatara & Kusumawardani, 2024). The greater the conversion of forests to agricultural land, the greater the emissions will be with greater density (Houghton, 2012). Production shocks in China are unable to affect carbon emissions in the short and long term, which means that the problem of deforestation is worse in that country (Rehman et al., 2021). Therefore, policies are needed to protect forest ecosystems and reduce GHG emissions from deforestation or forest degradation (Munawar et al., 2015).

With the country's awareness of the relationship between the environment and the economy, we have the opportunity to attract international attention to foreign direct investment (FDI). Countries with limited natural resources often use FDI as a means to stimulate economic growth through the inflow of capital, technology, and more advanced management practices into countries with greater natural resource potential. This collaboration arises to meet the economic needs of each party, making FDI a strategic aspect in strengthening industrial capacity and enhancing development. Indirectly, foreign direct investment is also a major cause of increased carbon dioxide (CO2) emissions.

However, the issue of foreign direct investment has the potential to damage the environment. This statement is in line with the results of research by Yamaka et al. (2021) that foreign direct investment will increase GHG emissions in China. In Nigeria, there is a two-way relationship between foreign investment and carbon emissions (Zubair et al., 2020). The consideration of foreign direct investment is its impact on energy intensity and its policy is expected to reduce emissions in the long term (H.E & Y, 2008; Zubair et al., 2020). Similarly, Mu Tashim & Rudatin (2023) found that FDI does not have a proven positive effect; rather, FDI can significantly reduce environmental emissions. This is similar to the results of Yamaka's research, but in the United States.

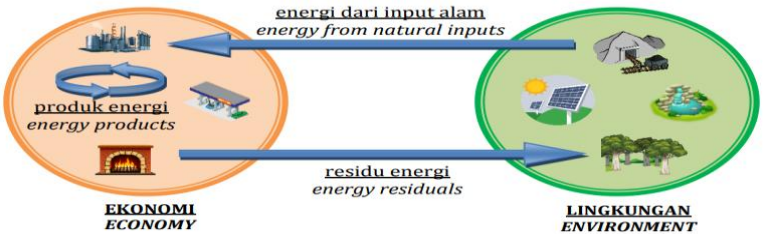

Figure 2.
Energy Flows Between the Economy and the Environment
Source: Indonesia's Energy Flow Balance and Greenhouse Gas Emissions Balance, 2025

Simply put, the depiction of energy input flows from the environment to the economy will return to the environment. Energy is produced from natural or environmental inputs. Furthermore, this energy production will be useful and circulate in the economy as household and industrial consumption. Household and industrial use will then have an impact back on the environment or nature. This is what makes researchers interested in studying issues related to carbon emissions, which are the economic impacts of or on the environment. Where high economic growth due to high demand to meet consumption can utilize renewable energy and avoid deforestation, it will bring foreign investment to Indonesia, and there are also differences in previous research results. Therefore, further observation and research are needed to see the

correlation between variables in the study.

RESEARCH METHOD

This study uses quantitative methods, with secondary data obtained from books, journals, statistical data from the Indonesian Central Statistics Agency, the World Bank, and Our World Data. The variables in this study are Carbon Emissions, Economic Growth, Energy Consumption, Deforestation, and Foreign Direct Investment. The data collection method in this study is time series from 1990 to 2022. Furthermore, it is analyzed using the VAR (Vector Autoregressive) analysis method, where data is collected and processed using Microsoft Excel and Eviews 12. This VAR test is carried out using the formula:

$$(EK)_t = EK\ [(EK_{t-p}), (GDP_{t-p}), (KE_{t-p}), (DF_{t-p}), (IA_{t-p})\ e_{1,t}\ ]$$
$$(GDP)_t = GDP\ [(GDP_{t-p}), (EX_{t-p}), (DF_{t-p}), (IA_{t-p}), (EX_{t-p})\ e_{1,t}\ ]$$
$$(KE)_t = KE\ [(PDB_{t-p}), (DF_{t-p}), (IA_{t-p}), (EK_{t-p}), (KE_{t-p})\ e_{1,t}\ ]$$
$$(DF)_t = DF\ [(GDP_{t-p}), (IA_{t-p}), (EK_{t-p}), (KE_{t-p}), (DF_{t-p})\ e_{1,t}\ ]$$
$$(IA)_t = IA\ [(GDP_{t-p}), (EK_{t-p}), (KE_{t-p}), (DF_{t-p}), (IA_{t-p})\ e_{1,t}\ ]$$

Explanation:

EK : Indonesia's Carbon Emissions (Mt CO2)
GDP : Economic Growth (%)
KE : Indonesia's Final Energy Consumption (kWh/$)
DF : Indonesia's Net Deforestation (%)
IA : Indonesia's Net Inflow of Foreign Direct Investment (%)

RESULTS AND DISCUSSION

Stationarity Test

To conduct this study, the first test that must be performed is the unit root test or stationarity test using Augmented Dickey-Fuller (ADF) until stationary data is obtained at the same degree (level or difference).

Table 1.
Unit Root Test Results (Level)

No	Research Variable	ADF t-statistics	Test Critical Value		Prob*	Description
			Level	Value		
1	EK	1.282234	1% level	-3.711457	0.9978	Non-stationary
			5% level	-2.981038		
			10% level	-2.629906		
2	GDP	-4.157702	1% level	-3.653730	0.0028	Stationary
			5% level	-2.957110		
			10% level	-2.617434		
3	KE	-0.506145	1% level	-3.653730	0.8773	Non-stationary
			5% level	-2.957110		
			10% level	-2.617434		
4	DF	-3.176131	1% level	-3.653730	0.0309	Stationary
			5% level	-2.957110		
			10% level	-2.617434		
5	IA	-2.202431	1% level	-3.653730	0.2093	Non-stationary
			5% level	-2.957110		
			10% level	-2.617434		

Source: Processed Data

Based on the results shown in Table 1, only the GDP and DF variables are stationary with prob values of 0.0028 and 0.0309 < 0.05. Meanwhile, the other variables in the study are not stationary at the level, as evidenced by the probability values, none of which are smaller than 0.05.

Table 2.
Unit Root Test Results (1st difference)

No	Research Variable	ADF t-statistics	Test Critical Value		Prob*	Description
			Level	Value		
1.	EK	-5.692615	1% level	-3.711457	0.0001	Stationary
			5% level	-2.981038		
			10% level	-2.629906		
2	GDP	-5.768686	1% level	-3.670170	0.0000	Stationary
			5% level	-2.963972		
			10% level	-2.621007		
3.	KE	-4.577317	1% level	-3.661661	0.0010	Stationary
			5% level	-2.960411		
			10% level	-2.619160		
4.	DF	-3.952529	1% level	-3.661661	0.0049	Stationary
			5% level	-2.960411		
			10% level	-2.619160		
5	IA	-5.366526	1% level	-3.661661	0.0001	Stationary
			5% level	-2.957110		
			10% level	-2.617434		

Source: Processed Data

After conducting unit root testing at the 1st difference level, it was found that all research variables in Table 2 are stationary or no longer contain unit roots. This means that all variables are I(1) or integrated for order 1.

Cointegration Test

The results of this test show that there are three cointegration relationships at a significance level of 5%. This is indicated by a test statistic value greater than the critical value and a probability value less than 0.05. Thus, the null hypothesis stating that there is no cointegration is rejected, and it is concluded that there is a long-term relationship between the variables in the model. Therefore, the equation must be solved using the VECM method rather than VAR. From Tables 4.4 and 4.5, it can be seen that there is an asterisk (*), so the equation must be solved using the Vector Error Correction Model (VECM) equation.

Table 3.
Trace Statistic Results

No	Hypothesis	Trace Statistic	Critical Value 5%	Prob	Description
1.	None*	166.5985	69.81889	0.0000	Tolak Ho
2	At most 1*	83.58914	47.85613	0.000	Reject Ho
3	At most 2*	34.35555	29.79707	0.0139	Reject Ho
4	At most 3	9.669350	15.49471	0.307	Accept Ho
5	At most 4	3.594702	3.841465	0.0580	Accept Ho

Source: Processed Data

Table 4.
Max-Eigen Statistic Results

No	Hypothesis	Trace Statistic	Critical Value 5%	Prob	Description
1.	None*	83.00937	33.87687	0.0000	Tolak Ho
2	At most 1*	49.23358	27.58434	0.000	Reject Ho
3	At most 2*	24.68620	21.13162	0.0151	Reject Ho
4	At most 3	6.074648	14.26460	0.6037	Accept Ho
5.	At most 4	3.594702	3.841465	0.0580	Accept Ho

Source: Processed Data

Granger Causality Test

From the results of the Granger Causality Test analysis in Table 4.6, out of 20 causality statements, 14 statements have a probability value > 5% and 10%, meaning that there is no causality between variables. Only 6 statements have a probability value ≤ 5% and 10%, meaning that there is causality between variables X and Y or vice versa.

Table 5.
Granger Causality Results

Null Hypothesis:	Obs	F-Statistic	Prob.
D(GDP) does not Granger cause D(EK)	29	0.28294	0.8371
D(EK) does not Granger cause D(GDP)		1.04093	0.3940
D(KE) does not Granger cause D(EK)	29	0.29789	0.8265
D(EK) does not Granger cause D(KE)		1.52927	0.2349
D(DF) does not Granger cause D(EK)	29	0.34846	0.7906
D(EK) does not Granger cause D(DF)		0.8985	0.4577
D(IA) does not Granger cause D(EK)	29	1.7656	0.1831
D(EK) does not Granger cause D(IA)		0.02747	0.9937
D(KE) does not Granger cause D(GDP)	29	1.82511	0.1721
D(GDP) does not Granger cause D(KE)		6.5836	0.002
D(DF) does not Granger cause D(GDP)	29	0.34034	0.7964
D(GDP) does not Granger cause D(DF)		21.1516	1.E-06
D(IA) does not Granger cause D(GDP)	29	1.20285	0.33
D(GDP) does not Granger cause D(IA)		4.14	0.01
D(DF) does not Granger cause D(KE)	29	4.85319	0.0097
D(KE) does not Granger cause D(DF)		2.42658	0.092
D(IA) does not Granger cause D(KE)	29	1.39167	0.2717
D(KE) does not Granger cause D(IA)		3.93198	0.0218

D(IA) does not Granger cause D(DF)	29	1.32569	0.2914
D(DF) does not Granger cause D(IA)		0.7385	0.5403

Source: Processed Data

This test shows that there is a short-term relationship or one-way Granger causality between economic growth and energy consumption with an F-statistic value of 6.58362 and a probability value of 0.0024, which is less than 0.05, indicating that changes in economic growth in the previous period can affect energy consumption in the following period. Given the relationship between economic growth and energy consumption, it is important to note that there is a high possibility of environmental damage, one of which is an increase in carbon emissions. This is reinforced by the findings of Dagher & Yacoubian (2012), which state that GDP will directly result in changes in energy consumption, known as the Conservation Hypothesis. Similarly, the results of research by Saidi & Hammami (2015) show that economic growth has a significant effect on energy consumption.

The short-term or one-way Granger causality relationship between economic growth and deforestation means that high economic growth will have an impact on deforestation in the following period, especially in developing countries due to the lack of mitigation measures and economic growth always being followed by natural exploitation. In the research by Woldemedhin et al. (2022), forest cover has a negative effect on economic growth, meaning that if forest cover increases due to conservation, the economic growth rate tends to decline.

Indonesia's environmental issues are a matter of global concern, especially since Indonesia is known as a country rich in natural resources. However, Indonesia's high rate of land conversion and deforestation is often used for mining development or the conversion of forest land into palm oil plantations.

In addition, there is also a short-term or one-way Granger causality relationship between economic growth and foreign direct investment. Basically, investments are made by considering many aspects of a company or country. These include economic, environmental, and political aspects. Unfavorable political issues will affect the economic instability of the country. Therefore, investors will think twice or even decide not to invest in the company or country. In their study, Comuk et al. (2023) also state that sustainable economic development effectively addresses climate issues and that conservative countries are selective in choosing the types of foreign direct investment that enter their countries.

There is also a short-term relationship or one-way Granger causality between energy consumption and foreign direct investment. A country's energy management will also be a special consideration for a country to invest. If a country is able to manage its energy availability appropriately, supported by wise pricing and policies, foreign investors will invest. Several countries that are aware of environmental issues are transitioning to clean energy sources, which can become green FDI destinations. This will reduce energy consumption and increase energy efficiency through better technology and lead to economic growth.

There is a two-way relationship or Granger causality between Deforestation (DF) and Energy Consumption (EC). Changes in deforestation can trigger an increase in energy consumption. For example, converting forest land into residential areas will increase energy demand, such as electricity and water. Similarly, changing the function of forest land to oil palm plantations will drive increased energy consumption, especially if there are factories around the plantations that require energy to operate machinery and heavy equipment. Thus, both the development sector and industries growing around areas affected by deforestation will drive increased energy demand. This is in line with the research by Woldemedhin et al. (2022) that forest cover has a positive and bidirectional effect on increasing energy consumption.

Based on Granger causality testing, a causal relationship was found between economic growth, energy consumption, deforestation, and foreign direct investment in both one-way and

two-way directions. However, no causal relationship was found with carbon emissions in Indonesia. Overall, the results of this study show that the dynamic relationship between economic and environmental variables in Indonesia is dominated by economic growth, which has a very strong impact on energy and the environment. Meanwhile, there is no significant causal relationship with carbon emissions in the short term. This indicates that carbon emissions are not yet a major consideration in economic decision-making in Indonesia, so that economic growth can continue without regard to the impact on the environment. This requires clear policies related to the environment and the economy.

Vector Error Correction Model (VECM)

Short-Term Relationship

Based on the results of the VECM test conducted with the variables of carbon emissions, economic growth, energy consumption, deforestation, and foreign direct investment, a short-term and long-term relationship was found between the variables in Indonesia from 1990 to 2022.

From the table above, it can be seen that economic growth does not affect carbon emissions in Indonesia in the short term. Several studies state that economic growth and energy consumption tend to increase carbon emissions in line with the country's development. Several studies also mention that economic growth and energy consumption can reduce carbon emissions. According to research by Yamaka et al (2021), which compares the United States and China, the world's highest contributors to carbon emissions, economic factors in China can increase greenhouse gas emissions. Meanwhile, in the United States, they can reduce greenhouse gases, even though both countries have implemented renewable energy production. These results are in line with Drean's (2022) research, which found that economic growth has a negative and significant impact on the environment, with air pollution harming Malaysia's economic growth in the short term.

Table 6.
Short-Term VECM Estimation Results for Carbon Emissions

Variable	Coefficient	Std. Error	t-Statistic	Probability
CointEq1	-0.0756	1.3010	-0.0581	0.9540
D(EK(-1),2)	-0.4423	1.0556	-0.4191	0.6797
D(EK(-2),2)	-0.6862	0.7100	-0.9666	0.3446
D(EK(-3),2)	-0.4642	0.6706	-0.6922	0.4966
D(GDP(-1),2)	0.4025	10.4961	0.0384	0.9696
D(GDP(-2),2)	1.7465	7.2359	0.2414	0.8116
D(GDP(-3),2)	-0.0746	4.9818	-0.0150	0.9879
D(KE(-1),2)	55.6256	407.111	0.1366	0.8920
D(KE(-2),2)	-286.3144	285.107	-1.0042	0.3273
D(KE(-3),2)	-38.8592	186.226	-0.2087	0.8363
D(DF(-1),2)	26.3642	22.0456	1.1959	0.2423
D(DF(-2),2)	11.8217	24.5667	0.4812	0.6345
D(DF(-3),2)	19.3928	15.1014	1.2842	0.2129
D(IA(-1),2)	0.8132	9.9445	0.0818	0.9351

D(IA(-2),2)	-2.8453	7.4480	-0.3820	0.7061
D(IA(-3),2)	-10.8337	8.7424	-1.2392	0.2304
C	-0.4300	4.7653	-0.0902	0.9286

Source: Processed Data

Although Indonesia has a high dependence on fossil fuels, which causes an increase in carbon emissions in Indonesia, in recent years Indonesia has begun to shift to the service and digital sectors, which have relatively lower emissions, indicating that in the short term, economic growth does not increase carbon emissions. Another example is in the city of Jakarta, where the GRDP tends to be high, but carbon emissions have not increased significantly and are fairly stable because it is an economic center and depends on fossil fuel transportation. According to data from the Ministry of Environment and Forestry and environmental studies, Jakarta's GHG emissions have not increased sharply but have tended to be stable since 2013–2022 (between 52–61 million tons of CO_2e per year). Economic growth has continued, but carbon emissions have been kept in check, even if they have not been reduced.

Energy consumption, deforestation, and foreign direct investment also do not affect the increase in emissions in Indonesia in the short term but affect other aspects. The short-term impact of deforestation can be reflected in other environmental impacts rather than additional carbon emissions. Due to the loss of land cover, the frequency of natural disasters such as floods and landslides has increased. If deforestation is carried out to clear land for oil palm plantations, the main problem that arises in the short term is socio-economic conflict.

Similarly, foreign direct investment in Indonesia has not been maximized, so in the short term it will not be felt and will not have an impact on emissions.The results of this study are in line with the research by Mu Tashim & Rudatin (2023), which states that FDI significantly reduces emissions in BRICS countries. Research by Yamaka et al. (2021) in the United States also shows that FDI can reduce emissions, but not in China, where FDI will increase emissions.

Long-Term Relationship

Table 7.
Long-Term VECM Estimation Results

Variable	Coefficient	SE	t-statistic
D(GDP(-1))	9.711511	(0.69771)	[13.9190]
D(KE(-1))	-4.629005	(24.2419)	[-0.19095]
D(DF(-1))	-3.498174	(1.24295)	[-2.81442]
D(IA(-1))	-14.93621	(1.44517)	[-10.3352]
C (constant)	-15.45987		

Source: Processed Data

Economic growth has a positive and significant relationship with carbon emissions in Indonesia. This finding is consistent with the Environmental Kuznets Curve (EKC) theory in the early stages of development, where an increase in GDP drives industrial activity and energy consumption, thereby increasing emissions. Thus, Indonesia is likely still in the early stages of the EKC curve, where economic development tends to neglect the environment, thereby increasing pollution and emissions.

In addition, there are no indications of a decline in emissions alongside economic growth. However, if economic development in Indonesia progresses rapidly and the government has a sense of responsibility towards the environment, policies should pay more attention to the environment and lead to a green economy, which can gradually reduce emissions.

The results of this study are in line with research conducted by Saidi & Hammami

(2015), Mu Tashim & Rudatin (2023), Yamaka et al. (2021), which states that economic growth is positively and significantly related to GHG emissions in the United States and China, as well as research in five BRICS countries. In addition, this study is also in line with the results of research by Azwar (2019), which found that economic growth in Indonesia had a significant positive impact on CO_2 emissions from 1981 to 2016. However, it is not in line with the research by Zubari et al. (2020), which states that economic growth has a negative and significant impact on carbon emissions because good economic performance can implement sustainable production.

Energy consumption tends to reduce emissions but is not statistically significant. This result contradicts the conventional theory that energy consumption, especially fossil-based energy, increases carbon emissions. This negative coefficient can be explained by a shift to renewable energy sources, increased energy efficiency, or a data structure that does not directly capture gross energy consumption. Over the three decades covered by this study, renewable energy in final energy consumption continued to decline, despite a slight increase in the early 2020s, but this increase did not have a significant impact on long-term carbon emission reductions. The results of this study are in line with the research by Yamaka et al. (2021) in the United States, but not in line with Rahman & Kashem (2017), Sterpu et al. (2018), Lismiyah et al. (2024).

Meanwhile, deforestation and foreign direct investment show a negative and significant relationship with carbon emissions in Indonesia; in other words, both can reduce carbon emissions. These results are not in line with environmental theory, which states that deforestation should increase carbon emissions. This decline can be explained by an increase in reforestation by the government, one of which is through land rehabilitation. According to BPS data from 2011 to 2018, the total area is around 2.9 million hectares, peatland restoration, unrecorded forest degradation, or changes in forest cover types.

The results of this study also support the pollution halo hypothesis, which states that FDI can improve environmental quality through the transfer of clean technology and more environmentally friendly industrial practices. This means that the influx of foreign direct investment will encourage a more sustainable industrialization process, as it generally brings more advanced production technology compared to domestic standards.

The results of this study are in line with the research by Demena & Afesorgbor (2020), which states that middle- and high-income countries can reduce emissions through FDI. According to the World Bank, based on the 2023-2024 income classification, Indonesia is classified as an upper-middle income country. Furthermore, this is also supported by the research of Yamaka et al. (2021), Zubair et al. (2020), and Mu Tashim & Rudatin (2023). All three mention that with foreign direct investment, foreign companies have more advanced technology and pay attention to the environment, so that industries will pay more attention to environmental impacts. However, this is not in line with the research by Derinhag et al. (2023).

Overall, the increase in carbon emissions in Indonesia is caused by economic growth. Indonesia still lacks a high level of awareness regarding environmentally conscious economic development. However, if it follows the EKC curve, it is expected that development in Indonesia, after passing the initial phase, will be followed by environmental improvement, as seen in studies in developed countries such as the United States, where economic growth is followed by a decrease in emissions.

Impulse Response Function

Based on the IRF estimation results, it shows that in the first period, economic growth, energy consumption, deforestation, and foreign direct investment did not cause any shocks to carbon emissions. In the seventh period, economic growth caused a 6.13% increase in carbon emissions. Energy consumption in the tenth period caused a decrease in carbon emissions of -0.97%. Deforestation in the fifth period reduced carbon emissions by -4.91%. Meanwhile,

foreign direct investment had the least impact on carbon emissions.

Variance Decomposition

The contribution of economic growth to carbon emissions in Indonesia from the first to the tenth period increased by around 8.44%. Similarly, the contribution of deforestation to carbon emissions increased from 0% in the first period to 13.87% in the tenth period. The contribution of energy consumption was less stable in the first six periods, then from the seventh to the tenth period, it continued to decline to 4.57% in the tenth period. Finally, the contribution of foreign direct investment to carbon emissions from the beginning to the tenth period did not increase significantly, ending at 0.18% at the end of the period.

CONCLUSION

The high increase in carbon emissions in Indonesia is caused by economic growth that still does not take the environment into account, with the fossil fuel industry. Thus, economic growth causes an increase in emissions in the long term. This is supported by variance decomposition testing, which shows that over ten periods, the contribution of economic growth to carbon emissions continues to increase. Meanwhile, energy consumption does not increase emissions, but this is not significant. Deforestation and Foreign Direct Investment with green FDI will be able to reduce emissions and not cause environmental issues, and can attract the attention of foreign investors and boost the Indonesian economy. The government is expected to be fully committed to sustainable development and implementing a green economy. It should review policies related to forests, the environment, and the maximum utilization of renewable energy.

REFERENCES

Adkins, E., Oppelstrup, K., & Modi, V. (2012). Rural household energy consumption in the millennium villages in Sub-Saharan Africa. 16 (3), 245–259. https://doi.org/10.1016/j.esd.2012.04.003

Appiah, M. O. (2018). Investigating the multivariate Granger causality between energy consumption, economic growth and CO2 emissions in Ghana. Energy Policy, 112 (October 2017), 198–208. https://doi.org/10.1016/j.enpol.2017.10.017

Aruga, K. (2019). Investigating the energy-environmental Kuznets curve hypothesis for the Asia-Pacific region. Sustainability (Switzerland), 11 (8). https://doi.org/10.3390/su11082395

Azwar. (2019). Investigating the Environmental Kuznets Curve Hypothesis Existence. Journal BPPK, 12 , 42–52. http://www.edc2020.eu/117.0.html

BMKG. (2022). Greenhouse Gases. Greenhouse Gas Bulletin, 2 (3), 27–28. https://iklim.bmkg.go.id/bmkgadmin/storage/buletin/Buletin Gas Rumah Kaca Vol 2 No 2_BMKG.pdf

Çomuk, P., Bagieńska, A., Akkaya, B., & Ercoşkun, S. (2023). The foreign direct investments, carbon (CO 2) emissions, and economic growth nexus: an empirical analysis for Turkey and European Union countries. WSB Journal of Business and Finance, 57 (1), 88–95. https://doi.org/10.2478/wsbjbf-2023-0010

Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., et al.(2025). GHG EMISSIONS OF ALL WORLD COUNTRIES. Joint Research Centre. https://doi.org/10.2760/5917997

Dagher, L., & Yacoubian, T. (2012). The causal relationship between energy consumption and economic growth in Lebanon. Energy Policy, 50 (2012), 795–801. https://doi.org/10.1016/j.enpol.2012.08.034

Demena, B. A., & Afesorgbor, S. K. (2020). The effect of FDI on environmental emissions:

Evidence from a meta-analysis. Energy Policy, 138 , 111192. https://doi.org/10.1016/j.enpol.2019.111192

Drean, B. (2022). Green Economy and Social Welfare in Malaysia: ARDL Approach. Tamansiswa Management Journal International, 4

Firdaus, Zanial Fahmi, Novalia, T., Puspita, Chaterina Dwi, Yuliani, E., Ardianti, Dela Maria, Logaritma, S., Hanaa, P., & Indryani, E. (2024). Energy Flow Balance and Greenhouse Gas Emissions Balance of Indonesia 2018-2022 (Vol. 4). Central Statistics Agency.

Gamatara, M. P. J., & Kusumawardani, D. (2024). The Effect of Deforestation on CO2 Emissions in Tropical Countries in Asia. Scientific Journal of Management, Economics, & Accounting (MEA), 8 (2), 1239–1256. https://doi.org/10.31955/mea.v8i2.4129

H.E, C., & Y, B. (2008). CO2 Emissions, Energy Consumption and Economic Growth in Tunisia. AgEcon Search, 12 . file:///F:/Spec 2/Traffic Delay Model.pdf

Houghton, R. A. (2012). Carbon emissions and the drivers of deforestation and forest degradation in the tropics. Current Opinion in Environmental Sustainability, 4 (6), 597–603. https://doi.org/10.1016/j.cosust.2012.06.006

Isbahi, M. B., Zuana, M. M. M., & Toha, M. (2024). The Multi-Social Relation of the Cattle Industry in the Plaosan Subdistrict Animal Market of Magetan Regency. *Malacca: Journal of Management and Business Development* , *1*(1), 31–46. https://doi.org/10.69965/malacca.v1i1.51

Kata Data Insight Centre. (2022). Indonesia Carbon Trading. Kata Data Insight Center, August, 1–77.

Ministry of National Development Planning/Bappenas. (2020). Green Economy Index: A Step Forward to Measure the Progress of Low Carbon and Green Economy in Indonesia. Bappenas, 39.

Lismiyah, E., Taher, A. R., Gunarto, T., & Aida, N. (2024). The Causality Between Energy Consumption and Carbon Emission in Indonesia.

Mahadiansar, M., Setiawan, R., Darmawan, E., & Kurnianingsih, F. (2021). The Reality of Foreign Direct Investment Development in Indonesia in 2019. Matra Pembaruan, 5(1), 65–75. https://doi.org/10.21787/mp.5.1.2021.65-75

Mu Tashim, T., & Rudatin, A. (2023). Economic analysis of BRICS countries on carbon dioxide (CO2) emissions. Journal of Economic and Financial Policy, 2 (2), 205–214. https://doi.org/10.20885/jkek.vol2.iss2.art12

Munawar, S., Khokhar, M. F., & Atif, S. (2015). Reducing emissions from deforestation and forest degradation implementation in northern Pakistan. International Biodeterioration and Biodegradation, 102 , 316–323. https://doi.org/10.1016/j.ibiod.2015.02.027

Novalia, T., Yuliani, E., Ardianti, dela maria, Istiqomah, N. P., Prisityowati, H., Puspita, chaterina dwi, Indryani, E., & Siallagan, M. A. H. (2025). INDONESIA'S ENERGY FLOW BALANCE AND GREENHOUSE GAS EMISSIONS BALANCE 2019-2023.

Nunez, C. (2019). Carbon dioxide levels are at a record high. Here's what you need to know. https://www.nationalgeographic.com/environment/article/greenhouse-gases

Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics, 36

Rahman, M. M., & Kashem, M. A. (2017). Carbon emissions, energy consumption, and industrial growth in Bangladesh: Empirical evidence from ARDL cointegration and Granger causality analysis. 110

Raihan, A., Hasan, M. A., Voumik, L. C., Pattak, D. C., Akter, S., & Ridwan, M. (2024). Sustainability in Vietnam: Examining economic growth, energy, innovation, agriculture, and forests' impact on CO2 emissions. World Development Sustainability, 4 (May

2023), 100164. https://doi.org/10.1016/j.wds.2024.100164
Rautner, M., Leggett, M., & Davis, F. (2013). Small Book, Big Driver of Deforestation. 11–225.
Rehman, A., Ulucak, R., Murshed, M., Ma, H., & Işık, C. (2021). Carbonization and atmospheric pollution in China: The asymmetric impacts of forests, livestock production, and economic progress on CO2 emissions. Journal of Environmental Management, 294 (January). https://doi.org/10.1016/j.jenvman.2021.113059
Saidi, K., & Hammami, S. (2015). The impact of CO2 emissions and economic growth on energy consumption in 58 countries. Energy Reports, 1 , 62–70. https://doi.org/10.1016/j.egyr.2015.01.003
Stern, D. I. (2004). The environmental Kuznets curve (EKC). Applied Economics Letters, 11 (7), 449–452. https://doi.org/10.1080/1350485042000207216
Sterpu, M., Soava, G., & Mehedintu, A. (2018). Impact of economic growth and energy consumption on greenhouse gas emissions: Testing environmental curves hypotheses on EU countries. Sustainability (Switzerland), 10 (9). https://doi.org/10.3390/su10093327
Secretariat General of the National Energy Council. (2019). Indonesia Energy Outlook 2019. Journal of Chemical Information and Modeling, 53(9), 1689–1699.
United Nations. (2015). The Paris Agreement. https://doi.org/10.4324/9789276082569-2
Usenata, N. (2018). Environmental Kuznets Curve (EKC): A Review of Theoretical and Empirical Literature. Mpra, 85024 . http://search.proquest.com/docview/2059124395/
Weisse, M., Goldman, E., & Carter, S. (2024). Forest Pulse: The Latest on the World's Forests. https://research.wri.org/gfr/latest-analysis-deforestation-trends
Woldemedhin, D. G., Assefa, E., & Seyoum, A. (2022). Forest Covers, Energy Use, and Economic Growth Nexus in the Tropics: A Case of Ethiopia. Trees, Forests and People, 8 (January), 100266. https://doi.org/10.1016/j.tfp.2022.100266
WWF. (2021). Deforestation Fronts: Drivers and Responses in a Changing World. https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/ocuoxmdil_Deforestation_fronts___drivers_and_responses_in_a_changing_world___full_report__1_.pdf?_ga=2.109566541.957472229.1706127810-658244077.1706127810
Yamaka, W., Phadkantha, R., & Rakpho, P. (2021). Economic and energy impacts on greenhouse gas emissions: A case study of China and the USA. Energy Reports, 7 , 240–247. https://doi.org/10.1016/j.egyr.2021.06.040
Zubair, A. O., Abdul Samad, A. R., & Dankumo, A. M. (2020). Does gross domestic income, trade integration, FDI inflows, GDP, and capital reduce CO2 emissions? An empirical evidence from Nigeria. Current Research in Environmental Sustainability, 2
Zuana, M. M. M., Toha, M., & Isbahi, M. B. (2024). Exploration of Community Empowerment in a Village as the Entrance to a Lake in East Java. *Malacca: Journal of Management and Business Development* , *1*(1), 47–55. https://doi.org/10.69965/malacca.v1i1.52