International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(1), 1040-1048.

Impact of Fossil Fuels on Climate and Economy in Indonesia

Erwinsyah Erwinsyah*

Universitas Indraprasta PGRI, South Jakarta, Indonesia. Email: erwinsyah.unindra@gmail.com

Received: 06 October 2025 **Accepted:** 20 December 2025 **DOI:** https://doi.org/10.32479/ijeep.22886

ABSTRACT

The use of fossil fuels and economic growth must be balanced with environmental concerns, and Indonesia is affected by these issues. To examine the relationship between its Gross Domestic Product (GDP), population, energy consumption, and Carbon Dioxide (CO2) emissions in Indonesia, using an econometric model, and utilizing data from the World Bank and Our World in Data, spanning 1995-2022. Several tests are used to assess stationarity, cointegration, short- and long-term dynamics, and the response of CO2 emissions to shocks from other variables. Increased energy consumption results in a significant increase in CO2 emissions, whereas economic growth (GDP) has a substantial negative effect, indicating decoupling. The long-term impact of the population shows a negative correlation, but it is not statistically significant. Energy consumption emerged as the most influential variable impacting long-term CO2 emissions, followed by GDP. Considering the long-term influence of energy and the short-term impact of population, Indonesia's policies should prioritize two areas: (1) Reducing emissions from energy consumption, rapidly shifting the energy system towards renewable sources, and implementing robust energy efficiency strategies; and (2) managing population growth and implementing sustainable development strategies to mitigate indirect impacts on resources and CO2 emissions.

Keywords: CO2 Emissions, Energy Consumption, Environmental Policy, GDP, Indonesia, Population.
JEL Classifications: O44, Q43, Q53, Q54

1. INTRODUCTION

Between 1992 and 2020, research in 95 countries demonstrated that global warming significantly affected unemployment rates, inflation, agriculture, and urbanization. These impacts vary by latitude, which affects unemployment rates in middle-income countries (Liu and Lin, 2023). Global warming has social consequences that affect the poor and the vulnerable. This highlights the importance of tailored responses to climate issues, particularly in diverse economies of developing countries, including Indonesia.

Since 2007, the "Comparing Climate Change Policy Networks" project has employed qualitative comparative research that draws on diverse data to examine how economic, political, and cultural factors have influenced the adoption of climate change policies across 20 nations (Antila et al., 2018). Environmental Economic Geography (EEG) examines the interrelationship between the environment and economic activity, aiming to integrate these findings with growth and sustainability theories to promote the success of sustainable development at both the regional and global levels (He et al., 2022). Such studies highlight the need for policy changes to reduce dependence on fossil fuels.

By analyzing climate change mitigation methods to achieve the two-degree target set by the Paris Agreement, it is possible to reduce fossil fuel consumption in transportation and energy by 2030, thereby increasing employment and gross domestic product (GDP). This policy shift is anticipated to result in a more equitable employment structure across numerous countries, especially within the mining and manufacturing sectors, which are central to low-carbon economic transitions (Alexandri et al., 2024).

The reliance on fossil fuels has led to numerous significant environmental issues, as highlighted by the Intergovernmental Panel on Climate Change (IPCC), which has identified global warming as a substantial risk to economic progress. Indonesia's unique characteristics necessitate a focused study of its specific challenges and attitudes towards global warming. Despite its great potential to mitigate global warming, Indonesia is struggling with the economic impacts of climate change (Johnson, 2014), a challenge compounded by the global threat of depleting fossil fuel reserves (Cirdei, 2020). Indonesia is one of the countries uniquely affected by these issues owing to its geography and economy. This research employed a case study methodology and analyzed raw data to investigate CO_2 emissions, energy use, and economic development, with the goal of offering a fresh perspective for developing environmental and climate change policies. Current research on carbon emissions often neglects comprehensive, dynamic analyses explicitly designed for Indonesia, presenting a broader or more limited regional perspective.

This study used econometric methods to assess both the immediate and long-term relationships among Indonesia's GDP, population, energy use, and CO_2 emissions, with the aim of equipping policymakers with essential information to craft strategies for climate change and sustainable development. Furthermore, this study aims to shed light on Indonesia's transition to a greener economy characterized by increased economic stability despite the adverse effects of global warming.

Policymaking and planning for sustainable development require an understanding of what this means to navigate the effects of global warming. Diffenbaugh and Burke (2019) observed that over the past 50 years, global warming has led to increased energy consumption. Brown et al. (2015) highlighted that this trend could negatively affect the health of individuals, communities, and nations. Numerous studies have shown that variables such as GDP, population, and energy consumption are significant for analyzing the economic impact of climate change (Francis and Adebayo, 2024). China and India's energy transitions, as well as Indonesia's struggle to reconcile economic growth with environmental sustainability, should help developing Asian governments forecast the social and economic issues associated with their energy transitions (Gribkova and Milshina, 2022).

This study demonstrated the decoupling of growth from fossil fuel use through successful energy and population policies (Guo et al., 2021). Indonesia continues to rely on fossil fuels despite its goal to reduce its carbon footprint. However, the government is facing challenges. A significant causal link between population growth and carbon emissions was evident.

2. LITERATURE REVIEW

2.1. Theoretical Explanation

The environmental Kuznets curve (EKC) theory suggests that as a country develops, it initially generates higher levels of pollution, which then decrease as development continues and matures. As the desired level of prosperity is achieved, society prioritizes environmental quality and invests in cleaner technologies (He et al., 2022).

The EKC theory also posits that industrial groups tend to increase environmental damage but subsequently prioritize the environment as economic growth and welfare improve. These positive changes result from various factors, including further structural shifts towards a service-based economy, cleaner technologies, increased public demand for a better environment, and stricter regulations.

Within the Indonesian context, the EKC suggests that the early stages of economic development, which are predominantly dependent on fossil fuels, will lead to increased CO_2 emissions. When Indonesia reaches a tipping point, the next question is when additional economic expansion will result in lower emissions, a transition from the manufacturing to the service sector, and the capacity to invest in greener technologies.

To thoroughly comprehend the relationship between energy consumption and economic progress, it is vital to examine it using diverse research methodologies. This framework encompasses four main scenarios: Energy-driven growth, in which energy drives growth; consumption-driven growth, in which growth drives energy consumption; the feedback hypothesis, in which the two influence each other; and the neutrality hypothesis, in which the two do not influence each other. Energy-driven growth is likely to be the most prevalent scenario in Indonesia, where economic growth is mainly dependent on increasing energy consumption, particularly fossil fuels (Cirdei, 2020). This connection underscores the difficulty of separating economic expansion from reliance on fossil fuels. Indonesia's fossil-fuel-based energy system means that, as the economy grows, demand for fossil fuels also increases (Sukanto et al., 2024).

In addition, population growth directly increases energy demand and CO_2 emissions. Indonesia is one of the world's most populous nations, and its population continues to increase. Along with economic growth, there has been a shift in birth and death rates. However, consumer trends and technological advancements have also affected the extent of population expansion's impact on environmental deterioration. To mitigate adverse impacts on vulnerable populations, such as higher energy costs for low-income households and job losses in the fossil fuel industry, environmental legislation and the use of renewable energy must be managed effectively. In addition, the carrying capacity theory plays a crucial role, positing that Earth and certain regions have a limited capacity to accommodate a certain number of people and to provide natural resources (Brown et al., 2015).

The field known as "climate economics" analyzes the potential gains and losses from reducing global warming. Climate change poses several risks to Indonesia's economy, including intense weather events, agricultural disturbances, and rising sea levels. Achieving long-term economic sustainability requires investments in climate change adaptation and mitigation strategies. The costs of using fossil fuels are not fully reflected in market prices; these costs should also consider the environmental costs and the needs of future generations (Diffenbaugh and Burke, 2019).

2.2. Empirical Literature

Research on economic growth and its relationship with carbon emissions has been extensive (Sukanto et al., 2024), but the empirical literature remains contradictory and sparse. One example is the inconsistency in the application and results of research related to the environmental Kuznets curve (EKC) theory. Studies that predict the tipping point at which environmental harm decreases as economic prosperity increases lend credence to this theory. However, other studies have found the opposite trend: a decoupling of economic growth and emissions that has become increasingly unsustainable over time.

The interplay among energy, GDP, and population growth is often inadequately incorporated into Indonesia's comprehensive econometric models. To determine the dynamics of the research results in the short- and long-term, a vector error correction model (VECM) test was conducted.

Furthermore, this study broadens its focus from economics to the social sustainability dimension (demographic pressures and energy choices) that affects vulnerable groups. This study developed a more integrated perspective on social, economic, and environmental challenges, building on the work of Liu and Lin (2023) and Francis and Adebayo (2024).

Countries that consume and utilize more energy tend to experience higher economic growth rates. Research highlights how the transition to clean energy hampers economic development (Effendi, 2024; Yan et al., 2024). Chandio et al. (2019) asserted that econometric methods were employed to examine the correlation between energy usage and GDP growth. Growing populations have proven that CO_2 emissions are affected. As Indonesia's population continues to grow, energy demand and consequently, emissions have increased significantly. One way to achieve this goal is to manage the population. Sasana and Putri (2018) conducted a study using panel and time-series data to determine the influence of population growth on emissions.

Research has examined how climate change might affect Indonesia's economy, focusing on its infrastructure, agriculture, and coastal areas. The negative effects of global warming on inflation, agriculture, and urbanization have contributed to rising unemployment. This study sheds light on the financial consequences of climate change and emphasizes the importance of adjusting existing policies (Liu and Lin, 2023). Antilla et al. (2018) examined the policy networks of 20 countries and found that economic, political, and cultural factors influence the adoption of climate change policies. He et al. (2022) discussed how economic growth is linked to environmental issues.

3. RESEARCH METHODOLOGY

This quantitative study uses statistical methods to examine how population growth, economic development, and fuel consumption are associated with environmental degradation. The World Bank supplied time-series data on population, GDP, and CO_2 emissions from 1995 to 2022, whereas Our World Data included data on energy use. Descriptive analysis was used to determine the distribution, trends, and understanding of the data, providing information on the characteristics of the variables.

This study employed an econometric model to examine the interrelationships among energy consumption, GDP, population, and CO_2 emissions in Indonesia. This study analyzed the importance of each variable in CO_2 emissions, both collectively and separately. The econometric model applied in this study is as follows.

$$LNPCO_2 = \beta_0 + \beta_1 * LNPEC + \beta_2 * LNPGDP + \beta_3 * LNPOP + \varepsilon \quad (1)$$

Where:

LN(PGDP) signifies GDP per capita, LN(PEC) denotes CO_2 emissions per capita, and LN(POP) represents population, all expressed in terms of the natural logarithm of the population. The symbol ε represents the standard error of the estimate value. This study used the Augmented Dickey-Fuller (ADF) and Johansen Cointegration tests to assess data stationarity, with an emphasis on investigating enduring relationships among the variables.

The vector error correction model (VECM) was employed to validate the long-term association and stability of the variables. The Breusch-Godfrey LM test was used to detect serial correlation, and the Breusch-Pagan-Godfrey test was used to examine heteroscedasticity, thereby ensuring the robustness of the regression model. Follow-up testing of the influence of population, GDP, and energy consumption on carbon emissions was conducted using ordinary least squares (OLS). Applying OLS yields coefficients for the research variables, which can be used to understand the elasticity of the resulting economic model.

A variance decomposition (VD) test was applied to examine the relationship between fluctuations in the research variables and CO_2 emissions. The VD test facilitates understanding fluctuations in CO_2 emission estimates. The impulse response function (IRF) demonstrates how CO_2 emissions react over time to changes in the research variables.

4. RESULT AND DISCUSSION

4.1. Result

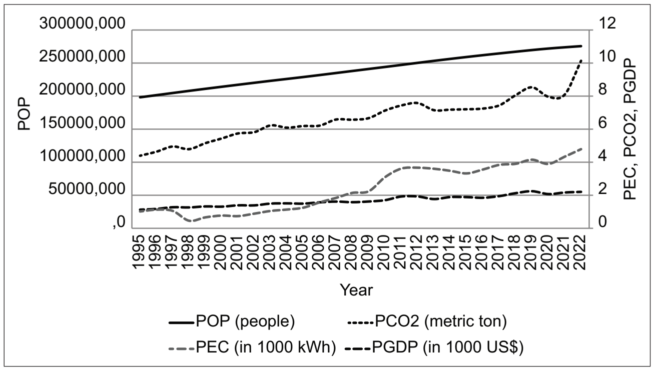
Figure 1 depicts trends in Indonesia's per-capita CO_2 emissions, energy use, GDP, and population from 1995 to 2022, highlighting notable increases over the study period.

4.1.1. CO_2 Emissions, energy, GDP, and population trends

Throughout the study period, per-capita CO_2 emissions increased by an average of 1.67 metric tons. The data indicate that from 1995 to 2022, Indonesia experienced a continuous rise in per capita CO_2 emissions alongside a general upward trend in energy consumption, despite some variations. In 2022, Indonesia's energy consumption will increase by 10 and 132 million tons from 4,392 million tons, or an average of 6,663 kWh.

Indonesia's economy has been on a firmer footing in the last several years, as evidenced by its rising Gross Domestic Product (GDP) per capita. From 1995 to 2022, the country's GDP per capita increased by US$3,767, from US$1,020 to US$4,787. The average GDP per capita of US$2,400 indicates improvements in living standards, increased buying power, and advancement in national development. Indonesia has a population of 238 million.

Figure 1: Trends in CO_2 emission, energy consumption, GDP, and population



Source: World Bank (2024); Ritchie et al., (2024)

4.1.2. Long-term relationship: Cointegration analysis

Cointegration tests revealed a long-term relationship among CO_2 emissions, energy consumption, and population across all three datasets.

4.1.3. Unit root tests and lag selection

Stationarity tests were performed on the time series data using the Augmented Dickey-Fuller (ADF) method. The results are shown in Table 1, which indicates that $LNPCO_2$ is stationary at the level, whereas LNPEC and LNPGDP become stationary after first differencing. Because the test results differed (level and first difference), the VECM test was used to evaluate the long-term equilibrium state.

As shown in Table 1, the variables $LNPCO_2$ and LNPOP remained unchanged. A test was performed to examine the long-term equilibrium. Subsequently, the optimal number of lags was identified using several statistical methods, including the final prediction error, Akaike information criterion, Schwarz information criterion, Hannan-Quinn information criterion, and the Likelihood ratio test. The findings indicated that a lag of 2 was the most appropriate, as validated by the stability test, which showed the modulus was <1, confirming the model's stability.

4.1.4. Cointegration test results: Johansen test

In this study, the vector error correction model (VECM) was selected because the variables were integrated of order 1 (I(1)). If the variables did not show this integration, the study opted for an Unrestricted Vector Autoregression (VAR) model. To verify the integration of the variables, the Johansen test was conducted, which included two key tests: the trace test and the maximum eigenvalue test.

According to the data presented in Table 2, the null hypothesis (H_0) regarding cointegration is rejected at the 5% significance level for all evaluated scenarios of cointegration equations, which include "None," "At Most 1," and "At Most 2." This rejection of H_0 confirms that the variables were cointegrated. The analysis concludes that there is a stable long-term association between the four variables under study: LNPEC, LNPGDP, LNPOP, and $LNPCO_2$.

Table 1: Augmented dickey-fuller test

Variables	t-statistic	P-value	Stationary
$LNPCO_2$	−4.389598	0.0093**	At Level
LNPEC	4.172775	0.0155**	At 1st difference
LNPGDP	−5.217179	0.0014**	At 1st difference
LNPOP	−7.994230	0.0000**	At Level

Source: Author's calculation results (2025)

4.1.5. Long-term effects: Vector error correction model

Table 3 illustrates the assessment of a single cointegration relationship through the vector error correction model (VECM). This relationship indicates that the variables achieve equilibrium in the long term. The VECM aids in analyzing short-term fluctuations and their adjustments to this long-term equilibrium.

Table 3 shows that CO_2 emissions ($LNPCO_2$) respond positively to energy consumption (LNPEC), supported by the VECM results, which indicate a coefficient of 0.645. The elasticity coefficient of $LNPCO_2$ in relation to LNPEC over the long term was measured at 0.645. The results of this study align with the work of Vo and Vo (2021); however, they differ from the conclusions reached by Farabi and Abdullah (2020). In contrast to the findings of Farabi and Abdullah (2020), who suggested that emissions contribute to robust growth, this study reveals that emissions impede growth.

The relationship between LNPGDP and $LNPCO_2$ is negative, with a coefficient of 0.180, suggesting that a 1% increase in LNPGDP results in a 0.18% decrease in $LNPCO_2$. However, the t-statistic result of −0.28072 shows that the population (LNPOP) has no significant long-term effect on $LNPCO_2$. The VECM results revealed that energy consumption (LNPEC) and GDP (LNPGDP) significantly influence CO_2 emissions in Indonesia. These results align with those of several studies on energy consumption and emissions in developing countries. However, the identified GDP-CO_2 decoupling distinguishes Indonesia's experience from previous, more pessimistic analyses, which emphasize the importance of researching policy reforms and technological advances specific to each country.

4.1.6. Granger causality tests

Table 4 presents the short-term interactions between the variables. A statistical value of $t < 2$ indicates an insignificant result at the 5% level. The error correction term (Coint Eq1) for D($LNPCO_2$) has a t-statistic of −1.12, suggesting a slight movement towards long-term equilibrium. Variables D(LNPEC), D(LNPGDP), and D(LNPOP) exhibit minimal short-term effects. Energy consumption (D(LNPEC)) is the sole variable that exhibits a significant adjustment to short-term imbalances, as evidenced by a t-statistic of −2.51, thereby contributing to the overall stabilization of the system.

Table 5 shows the outcomes of the Granger causality test, which was used to analyze the interaction between the variables.

As shown in Table 5, there was no evidence that LNPEC caused $LNPCO_2$ ($P = 0.6736$). Likewise, the relationship between LNPGDP and $LNPCO_2$ is tenuous, with a $P = 0.2987$. Nevertheless, LNPOP had a substantial causal impact on

Table 2: Johansen cointegration test result

Trace unrestricted cointegration rank test				
Hypothesized No. of CE (s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical value**	**Probability****
None*	0.888768	121.7910	55.24578	0.0000
At most 1	0.837631	69.08378	35.01090	0.0000
At most 2	0.632753	25.45454	18.39771	0.0044
At most 3	0.057185	1.413247	3.841466	0.2345
Maximum eigenvalue of unrestricted cointegration rank test				
Hypothesized No. of CE (s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical value**	**Probability****
None*	0.888768	52.70727	30.81507	0.0000
At most 1	0.837631	43.62924	24.25202	0.0001
At most 2	0.632753	24.04129	17.14769	0.0043
At most 3	0.057185	1.413247	3.841466	0.2345

Source: Author's calculation results (2025)

Table 3: Long-term performance of the vector error correction model

	Variable	Coefficient	t-statistic
$LNPCO_2(-1)$	LNPEC(−1)	0.645046	2.09894
	LNPGDP(−1)	−0.180071	−3.24406
	LNPOP(−1)	−0.268612	−0.28072

Source: Author's calculation results (2025)

Table 4: Short-term vector error correction model

	Variable	Coefficient	t-statistic
D ($LNPCO_2$)	Coint (Eq1)	−0.141855	−1.11893
	D ($LNPCO_2(-1)$)	−0.118387	−0.36653
	D (LNPEC(−1))	0.017547	0.05289
	D (LNPGDP(−1))	0.024058	0.46350
	D (LNPOP(−1))	1.201490	0.71142
	C	0.015486	0.68534
D (LNPEC)	Coint (Eq1)	−0.275766	−2.50669
	D ($LNPCO_2(-1)$)	0.256655	0.91571
	D (LNPEC(−1))	−0.222900	−0.77432
	D (LNPGDP(−1))	0.025688	0.57031
	D (LNPOP(−1))	−0.323643	−0.22084
	C	0.024860	1.26787
D (LNPGDP)	Coint (Eq1)	0.921655	1.58861
	D ($LNPCO_2(-1)$)	−2.082997	−1.40924
	D (LNPEC(−1))	0.067038	0.04416
	D (LNPGDP(−1))	−0.075211	−0.31664
	D (LNPOP(−1))	7.878681	1.01941
	C	0.015036	0.14541
D (LNPOP)	Coint (Eq1)	0.002077	0.11322
	D ($LNPCO_2(-1)$)	−0.038968	−0.83390
	D (LNPEC(−1))	0.025918	0.54002
	D (LNPGDP(−1))	−0.002671	−0.35575
	D (LNPOP(−1))	0.182196	0.74567
	C	0.011002	3.36546

Source: Author's calculation results (2025)

Table 5: Pairwise granger causality tests

Null hypothesis:	Obs	F-statistic	Probability
LNPEC does not affect Granger $LNPCO_2$	26	0.40270	0.6736
$LNPCO_2$ is not the cause of LNPEC		0.54327	0.5888
LNPGDP does not affect Granger $LNPCO_2$	26	1.28062	0.2987
$LNPCO_2$ does not cause Granger LNPGDP		3.30962	0.0563
LNPOP is not a Granger Cause $LNPCO_2$	26	9.46669	0.0012
$LNPCO_2$ does not cause Granger LNPOP		2.30318	0.1246
LNPGDP does not affect Granger Cause LNPEC	26	0.06477	0.9375
LNPEC is not a Granger Cause LNPGDP		5.09079	0.0158
LNPOP does not have a Granger Cause LNPEC	26	8.50277	0.0020
LNPEC is not the cause of LNPOP		1.10264	0.3505
LNPOP does not have a Granger Cause LNPGDP	26	6.28775	0.0072
LNPGDP is not caused by LNPOP		2.28797	0.1262

Source: Author's calculation results (2025)

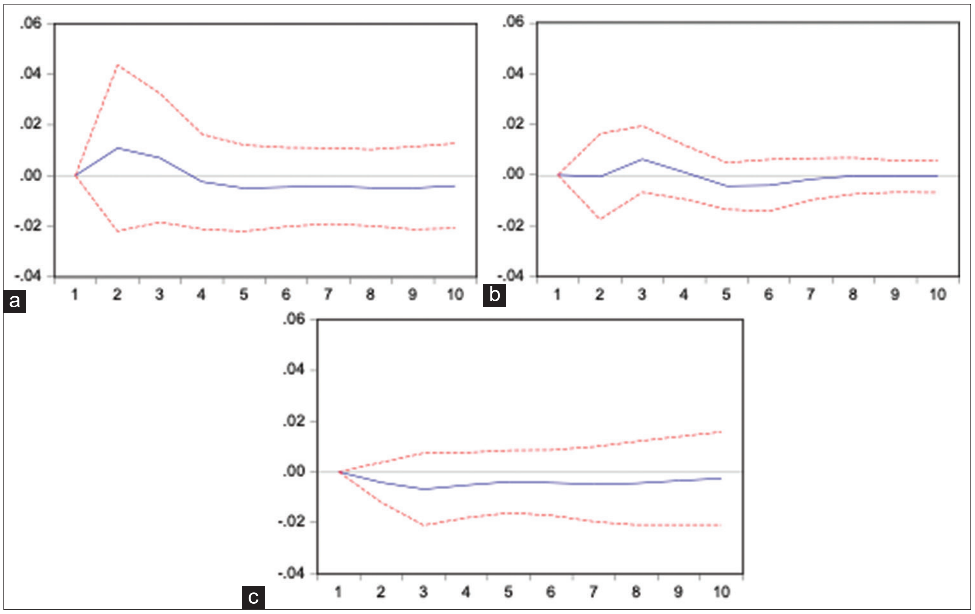
$LNPCO_2$, with a P-value as low as 0.0012. Understanding the causes of these trends can enable policymakers to take direct action to reduce emissions, while promoting long-term economic growth (Wu and Hou, 2020).

4.1.7. Impulse response function and variance decomposition analysis

The impulse response function (IRF) was used to investigate the behavior of CO_2 emissions per capita ($LNPCO_2$), facilitating the analysis of how these emissions respond to various disturbances. Variance decomposition (VD) was utilized to determine the influence of various factors on the estimation error. The Granger causality test results highlight the significant influence of per capita energy consumption (LNPEC) and population (LNPOP), underscoring the need to include these factors in any $LNPCO_2$ modeling endeavor.

In addition, IRF and VD analyzed the effects of individual factors and their interactions in this study. Figure 2a-c are examples of the extensive results of these analyses, in which the IRF study specifically aims to test PCO_2's responsiveness to the effects produced by the identified stimuli: PEC, PGDP, and POP. In particular, the IRF enables us to trace the time path of CO_2 emissions in response to the 1-time impact of the other variables, showing the size and duration of the shocks.

Figure 2: Respond of PCO_2 to PEC (a), PCO_2 to PGDP (b), PCO_2 to POP (c)



Source: Author's calculation results (2025)

Figure 2a illustrates that a shock to the PEC results in an initial rise in $LNPCO_2$, reaching a peak of approximately 0.04 2 years later, before declining progressively and converging at −0.02 after 10 years. As shown in Figure 2b, the responses of $LNPCO_2$ to a shock from PGDP remained positive during the 10-year period, initially on the order of 0.02 and increased over time to stabilize at around 0.04 by the 10th year. $LNPCO_2$ exhibits a favorable response to a POP shock, attaining a value of 0.06 at the conclusion of the 2nd year, as shown in Figure 2c, and stabilizes at approximately 0.02 from year 6 onward.

Variance decomposition (VD) analysis was employed to examine the impact of the PEC (per capita energy consumption), PGDP (per capita GDP), and POP (population) variables on PCO_2. Table 6 presents the VD analysis

Impact of various factors on per-capita CO_2 emissions (PCO_2) during ten periods. The lagged values of PCO_2 explain the entire variance in PCO_2 at lag 0 (100%), but this decreases over time. The initial dominance of the previous PCO_2 values provides evidence of their enduring influence on CO_2 emissions. Following the second period, 91.75% of the variance in PCO_2 is accounted for by PCO_2 itself and 7.15% by energy consumption (LNPEC), while the influence of population (LNPOP) and GDP (LNPGDP) is nearly negligible. The econometric analysis indicates that energy consumption is the most statistically significant factor accounting for CO_2 emissions over the longest forecast period. This implies that over time, energy consumption becomes increasingly dominant in explaining CO_2 emissions. Different temporal behaviors illustrate how changeable the issue is. The evidence they provide within this dynamic evolution speaks directly to the challenging time-varying association among these variables and the need for an adaptive policy. Over the 10 periods, the contribution of PCO_2 to the variance fell, constituting 75.48% by period ten. LNPEC, on the other hand, continued to expand its clout, mustering 12.91%, with LNPOP and LNPGDP receiving 8.14% and 3.47%, respectively.

Table 6: PCO_2 variance decomposition

Period	S.E.	$LNPCO_2$	LNPEC	LNPGDP	LNPOP
1	0.038532	100.0000	0.000000	0.000000	0.000000
2	0.040369	91.75225	7.146850	0.026675	1.074227
3	0.043936	86.05828	8.558536	2.035487	3.347693
4	0.044649	84.74592	8.583576	2.020041	4.650465
5	0.045558	82.45284	9.482248	2.877805	5.187106
6	0.046490	80.52454	10.07954	3.553646	5.842273
7	0.046977	78.93630	10.65032	3.610432	6.802949
8	0.047437	77.41513	11.46987	3.549476	7.565520
9	0.047862	76.18786	12.34930	3.502070	7.960766
10	0.048182	75.47866	12.90898	3.469122	8.143236

Source: Author's calculation results (2025)

Prioritizing the urgent need for a rapid national energy transition while accounting for the long-term impacts of energy use on CO_2 emissions is crucial to Indonesia's climate and energy policies. Environmentally friendly energy sources include geothermal, solar, and hydropower, and the government prioritizes investment in these areas. Furthermore, all industries must increase their energy efficiency. Policies must also promote eco-literacy, alter consumer habits, build low-carbon public infrastructure, and foster sustainable urban development to effectively address population increase and CO_2 emissions. These programs can also be strengthened by adopting green farming practices and providing smallholder farmers with the necessary incentives.

4.2. Discussion

Indonesia's per capita CO_2 emissions increased continuously from 1995 to 2022, averaging 1.67 metric tons over the entire period. In 2020, the global average carbon dioxide emissions per person were 4.3 metric tons/year (Nowarski, 2022). As a result, Indonesia's per capita greenhouse gas emissions are well below the global average. This is due to CO_2 emissions and environmental concerns. Another study comparing CO_2 emissions and economic growth across five ASEAN countries (Buana and Hidayat, 2024) found fascinating patterns, including Indonesia's M-shaped Environmental Kuznets

Curve and Singapore's status as a low-emission country with rapid economic development.

Carbon emissions continue to rise owing to increased industrialization (Sari, 2022), urbanization, and economic development, leading to increased energy consumption (Chontanawat, 2020) and reliance on fossil fuels. Coal is one of the most important primary energy resources. It offers the lowest power generation costs and has vast coal reserves (Bobei and Ciolea, 2022). The elevated carbon intensity of energy production is mainly due to increased coal use, especially in India and other rapidly developing Asian nations (UNESCAP, 2023).

From 1995 to 2022, Indonesia saw energy use per person rise from 4,392 kWh to 10,132 kWh, with an average consumption of 6,663 kWh. Indonesia's energy consumption has increased since 1995. All of these point to an increase in energy demand. In this study, the average per-capita energy consumption was found to be comparable to that reported in another study conducted during the same period, which was 6,669.1 kWh (Ritchie and Roser, 2022). This investigation indicates parallels between the two studies. It is necessary to immediately push for solutions that use less renewable energy to lessen the damage that rising demand causes to the Earth. Indonesia must switch to renewable energy to combat global warming. This shows that different levels of government and cooperation are required to improve the renewable energy industry and make the world more competitive (Sharvini et al., 2018).

Indonesia experienced consistent economic growth between 1995 and 2022, with its per capita GDP increasing from USD 1,020 to USD 4,787, averaging USD 2,400. This trend indicates improved living standards, increased purchasing power, and progress in the national development. Indonesia's per capita GDP is lower than Malaysia's, at USD 4,405 in 1995 and USD 11,993 in 2022 (World Bank, 2024).

Indonesia's per capita GDP has also increased from 1995 to 2022, indicating that the economy is growing and living standards are improving (Hill, 2021). However, carbon emissions have continued to increase owing to increased urbanization, industrialization, and consumption. Policymakers face a notable challenge in balancing economic development and environmental sustainability (Ali et al., 2023).

Indonesia's population increased by 77.4 million people between 1995 and 2022, from 198.1 million to 275.5 million. There was an average of 238 million people during this period. This has presented challenges for the economy, infrastructure, and social services seeking to expand (Hill, 2021). Reduced carbon emissions and social development in Indonesia depend on the growing population. As the population grows, so does energy demand, urbanization, and resource consumption, all of which can increase carbon emissions. Population management and family planning strategies are crucial for supporting sustainable development (Dodson et al., 2022).

Cointegration studies have shown a long-term correlation between population dynamics, energy use, and CO_2 emissions. This implies that these elements tend to converge over time, even in the face of possible short-term fluctuations in data. The emphasis is on encouraging climate-compatible, sustainable growth and on reevaluating population policy and energy use in a broader context (Mitić et al., 2022).

Over a period of 10 years, the contribution of per capita CO_2 emissions (PCO_2) to variance will reduce to 75.48%, while per capita energy consumption (LNPEC) will rise to 12.91%. Similarly, population (LNPOP) and per capita GDP (LNPGDP) are expected to increase by 8.14% and 3.47%, respectively. According to this study, energy use explains empirical CO_2 emissions, and population growth is increasingly being recognized as a direct driver of CO_2 emissions. However, GDP had an essential yet statistically insignificant effect. By reducing CO_2 emissions, Indonesia can manage its energy consumption and population growth over time.

These outcomes align with those reported by Wu and Hou (2020), who found a similar pattern in developing countries. These patterns suggest that, as their economies expand (through economic growth), emissions initially increase; however, as GDP per capita rises and the economy matures, emissions may begin to decrease. The study indicates a "fundamental" reason: both population growth and per capita energy use significantly influence reductions in CO_2 emissions. However, the opposite trend occurs with GDP growth. These results align with those of Vo and Vo (2021), who stated that population and energy consumption are the two critical factors influencing carbon emissions in Southeast Asia.

According to Farabi and Abdullah (2020), this implies that CO_2 emissions and regional GDP are positively and significantly related. The percentage contribution study corroborates that the key predictors of CO_2 emissions are individual, GDP, population, and energy use, in that order. This study also reminds us that population growth and measures to reduce energy consumption are essential for achieving targets for reduced carbon emissions (Kriegler, 2014).

By contrast, in the global context, Indonesia occupies a much more nuanced position, where its reliance on oil and gas as an energy source renders it ineffective in reducing carbon emissions while still maintaining an impressive, albeit temporary, rate of population growth. It also highlights the need for policy emphasis on renewable energy development in the context of population changes. This study also shows that CO_2 emissions can be significantly reduced by implementing policies such as sustainable energy consumption and population policies (Kriegler, 2014).

The significance of project-level cooperation and managerial decision-making has been emphasized. These figures elucidate the implications of policies for socioeconomic development and carbon emission reductions in Indonesia. The government must focus on controlling population growth, implementing efficient energy use, and prioritizing renewable energy sources. The implementation of energy-saving policies encourages the growth of environmentally friendly energy (Chontanawat, 2020). A country's future lies in achieving greater economic growth by effectively managing its carbon emissions. Insufficient environmental protection frameworks hinder the achievement of low-carbon emissions in Indonesia, despite the need for economic development (Raihan et al., 2022).

Both short- and long-term actions must be the focus of legislation to ensure the use of clean and sustainable energy. Furthermore, further research is required to identify ways to finance investments in low-energy technologies and clean energy solutions. The national development plan must incorporate programs to address family planning and population control to restrain population growth and support economic development (Starbird et al., 2016).

5. CONCLUSION

Indonesia faces a significant challenge in ensuring that economic development does not contribute to increased greenhouse gas emissions. This study emphasizes the long-term energy consumption associated with population growth, which is a significant driver of long-term CO_2 emissions, particularly given Indonesia's continued heavy reliance on fossil fuels. On a positive note, Indonesia's economic growth (GDP) has begun to exert a negative or reducing influence on its emissions. This indicates a move towards greater resource efficiency, an essential step in decoupling economic development from environmental pollution.

In the short term, population expansion serves as a robust and dependable indicator of immediate CO_2 surges, whereas fluctuations in energy consumption function as the principal self-regulating mechanisms within the system. Because CO_2 emissions are heavily influenced by past levels, accounting for approximately 75% of future behavior, any mitigation strategy requires a powerful, sustained effort to break this inertia. To achieve sustainable growth, Indonesia must immediately pursue a swift transition to renewable energy and robust energy-efficiency programs to tackle long-term energy drivers. Concurrently, implementing effective population and sustainable urban management strategies is critical for controlling the short-term pressure on emissions. Ultimately, achieving a sustainable, low-carbon future requires firm political resolution and a strategic plan that targets energy consumption and population growth at their respective time horizons.

REFERENCES

Alexandri, E., Antón, J.I., Lewney, R. (2024), The impact of climate change mitigation policies on European labour markets. Ecological Economics, 216, 108022.

Ali, M.A., Kamraju, M., Sonaji, D.B. (2023), Economic policies for sustainable development: balancing growth, social equity, and environmental protection. ASEAN Journal of Economic and Economic Education, 3(1), 23-28.

Antilla, T.Y., Gronow, A., Stoddart, M.C.J., Broadbent, J., Schneider, V., Tindall, D.B. (2018), Climate change policy networks: Why and how to compare the across countries. Energy Research Social Science, 45, 258-265.

Bobei, V., Ciolea, D. (2022), Aspects regarding the use of coal in the production of electrical and thermal energy. Sciendo, 28(3), 59-64.

Brown, M.E., Antle, J.M., Backlund, P., Carr, E.R., Easterling, W.E., Walsh, M.K., Ammann, C., Attavanich, W., Barrett, C.B., Bellemare,M.F., Dancheck, V., Funk, C., Grace, K., Ingram, J.S.I., Jiang, H.,… & Tebaldi, C. (2015), Climate Change, Global Food Security, and the U.S. Food System. United States: U.S. Department of Agriculture.

Buana, C.P., Hidayat, R.W. (2024), Dampak pertumbuhan ekonomi, urbanisasi dan konsumsi energi listrik terhadap degradasi lingkungan: Bukti dari negara asean-5. Jurnal Ilmu Ekonomi, 8(1), 31765.

Chandio, A.A., Jiang, Y., Sahito, J.G.M., Ahmad, F. (2019), empirical insights into the long-run linkage between household's energy consumption and economic growth: Macro-level empirical evidence from Pakistan. Sustainability, 11(22), 6291.

Chontanawat, J. (2020), Relationship between energy consumption, CO_2 emission, and economic growth in ASEAN: Cointegration and causality model. ScienceDirect, 6, 660-665.

Cirdei, I.A. (2020), The end of oil and its impact on national and collective security. Land Forces Academy Review, 25(1), 1-7.

Diffenbaugh, N.S., Burke, M. (2019), Global warming has increased global economic inequality. PNAS, 116(20), 9808-9813.

Dodson, J., Dérer, P., Cafaro, P., Götmark, F. (2022), Population growth, family planning and the Paris agreement: An assessment of the nationally determined contributions (NDCs), International Environmental Agreements Politics Law and Economics, 22(3), 561-576.

Effendi, S.A. (2024), Clean energy transition and intertemporal socio-economic development: A case study of households in Indonesia. Journal Research of Social Science Economics and Management, 4(1), 104-124.

Farabi, A., Abdullah, A. (2020), Environmental degradation in Indonesia and Malaysia: The effect of energy consumption, economic growth, population, and foreign direct investment (FDI). Jurnal Manajemen Teori dan Terapan, 13(2), 160-177.

Francis, O.E., Adebayo, G.D. (2024), The impact of climate change on the economies of developing countries. International Journal of Science and Research Archive, 13(2), 3223-3236.

Gribkova, D., & Yulia Milshina, Y. (2022). Energy transition as a response to energy challenges in post-pandemic Reality. Energies, 15(3), 812.

Guo, J., Li, C.Z., Li, C.Z., Wei, C. (2021), Decoupling economic and energy growth: Aspiration or reality? Environmental Research Letters, 16(4), 044017.

He, C., He, S., Mu, E., Peng, J. (2022), Environmental economic geography: Recent advances and innovative development. Geography and Sustainability, 3(2), 152-163.

Hill, H. (2021), What's happened to poverty and inequality in Indonesia over half a century? Asian Development Review, 38(1), 68-97.

Johnson, A. (2014), The Implication of Indonesia's Economic Development for Global Climate Change. Available from: https://lup.lub.lu.se/student-papers/record/4616614/file/4616620.pdf

Kriegler, E., Weyant, J.P., Blanford, G.J., Krey, V., Clarke, L., Edmonds, J., Fawcett, A., Luderer, G., Riahi, K., Richels, R., Rose, S.K., Tavoni, M., Vuuren, D.P. (2014), The role of technology for achieving climate policy objectives: Overview of the EMF 27 study on global technology and climate policy strategies. Climatic Change, 123, 353-367.

Liu, Y., Lin, T.Y. (2023), Does global warming affect unemployment? International evidence. Economic Analysis and Policy 80, 991-1005.

Mitić, P., Fedajev, A., Radulescu, M., Rehman, A. (2022), The relationship between CO_2 emissions, economic growth, available energy, and employment in SEE countries. Environmental Science and Pollution Research, 30, 16140-16155.

Nowarski, J. (2022), CO_2 Emission Per Capita. Geneva: Zenodo.

Raihan, A., Ahmed, D., Islam, M., Faruk, O. (2022), An econometric analysis of the potential emission reduction components in Indonesia. Cleaner Production Letters, 3, 100008.

Ritchie, H., Rosado, P., & Roser, M. (2024, October 1). Indonesia: Energy Country Profile. https://ourworldindata.org/energy

Sari, V.K. (2022), The impact of macroeconomic indicators on carbon emission in Indonesia. Jurnal Perspektif Pembiayaan dan Pembangunan Daerah, 10(1), 53-62.

Sasana, H., Putri, A.E. (2018), The increase of energy consumption and carbon dioxide (CO_2) emission in Indonesia. E3S Web of Conferences, 31(01008), 1-5.

Sharvini, S.R., Noor, Z.Z., Chong, C.S., Stringer, L.C., Yusuf, R.O. (2018), Energy consumption trends and their linkages with renewable energy policies in East and Southeast Asian countries: Challenges and opportunities. Sustainable Environment Research, 28(6), 257-266.

Starbird, E., Norton, M., Markus, R. (2016), Investing in family planning: Key to achieving the sustainable development goals. Global Health Science and Practice, 4(2), 191-210.

Sukanto, S., Azwardi, A., Hamira, H., Atiyatna, D.P. (2024), The unsustainable path: Assessing Indonesia's reliance on fossil energy in economic growth. International Journal of Energy Economics and Policy, 14(2), 484-489.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). (2023), Accelerating the Energy Transition. Switzerland: World Economic Forum.

Vo, D.H., Vo, A.T. (2021), Renewable energy and population growth for sustainable development in the southeast Asian countries. Energy Sustainability and Society, 11(30), 1-15.

World Bank. (2024, October 1). Total Greenhouse Gas Emissions Excluding LLUCF Per Capita (T CO_2e/capita)-Indonesia. Available from: https://data.worldbank.org/indicator/en.ghg.all.pc.ce.ar5?locations=id

Wu, Z., Hou, G. (2020), The causality between participation in gvcs, renewable energy consumption and CO_2 emissions. Sustainability, 12(1237), 1-26.

Yan, S., Zhang, Z., Yue, X.T., Liu, Y. (2024), Pathway for four Central and Eastern European countries to achieve low carbon development based on the STIRPAT model. Journal of Sustainable Development, 17(4), 63.