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Assessing The Effects of GDP and FDI Inflows on Carbon Dioxide Emission

Anindita Virgia Fanny Sazuli
Development Economics, Faculty of Economics and Business,
Universitas Brawijaya, Indonesia

Abstract: Indonesia is one of the world's largest emitters of carbon dioxide. This aligns with the Environmental Kuznets Curve (EKC) hypothesis, which states that economic growth initially causes environmental damage. This study uses the Error Correction Model (ECM) with time series data from 2002-2022 to definitively examine the relationship between sectoral GDP and FDI inflows with CO2 emissions in Indonesia. The results show that sectoral GDP significantly negatively affects CO2 emissions in the long and short run. In contrast, the quadratic form of GDP has a positive effect, indicating an anomaly in the expected EKC pattern. Moreover, FDI inflows significantly affect CO2 emissions only in the long run. These findings highlight the urgent need for policymakers to implement environmentally sustainable economic development strategies in Indonesia.

Keywords: Carbon Dioxide Emissions; Environmental Kuznets Curve (EKC); Sectoral GDP; FDI Inflows

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CORRESPONDING AUTHOR
Anindita Virgia Fanny Sazuli
aninditafanny@student.ub.ac.id

Fakultas Ekonomi dan Bisnis,
Universitas Brawijaya,
Indonesia

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INTRODUCTION

Indonesia is one of the largest economies in Southeast Asia and has experienced strong growth over the past decade (World Bank, 2023b). This has been driven by domestic consumption, investment, natural resource exploitation, and government-supported infrastructure development. The Government Work Plan (RKP) for 2023 targets 5-5.5% economic growth through national priority programs designed to stimulate strategic sectors and promote multiplier effects on the broader economy (Bappenas, 2023). National Priority Programs are expected to boost GDP growth in strategic sectors, thereby increasing the economy's overall performance. In addition to GDP, foreign direct investment (FDI) has become a significant growth engine, with inflows increasing by 46.7% to $45.6 billion in 2022 (Ministry of Investment/BKPM, 2020). Policies such as the Job Creation Law, tax incentives, and establishing special economic zones have increased Indonesia's attractiveness to international investors. Figure 1 visually represents the evolution of realized FDI inflows in Indonesia.

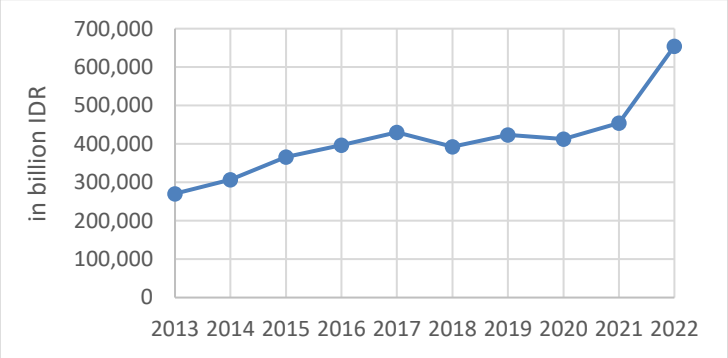


Figure 1. Evolution Of Realized Fdi Inflows In Indonesia (Source: Kementerian Investasi/Bkpm, 2020)

This rapid economic growth has come at an environmental cost. Indonesia is faced with balancing economic growth and environmental sustainability, particularly in light of rising carbon dioxide (CO_2) emissions. By 2022, Indonesia's CO_2 emissions will increase by 6.34% to 698 MtCO2, accounting for 1.6% of global emissions. (Crippa et al., 2022)The main contributors are the energy sector (43%), transport (25%), and industrial activities (23%) (Climate Transparency, 2022). Furthermore, BPS data on GDP by business field for 2012-2022 indicate a general increase in the total value of GDP. The existence of a parallel pattern between GDP development and CO_2 emissions suggests the applicability of the EKC (Environmental Kuznets Curve) hypothesis.

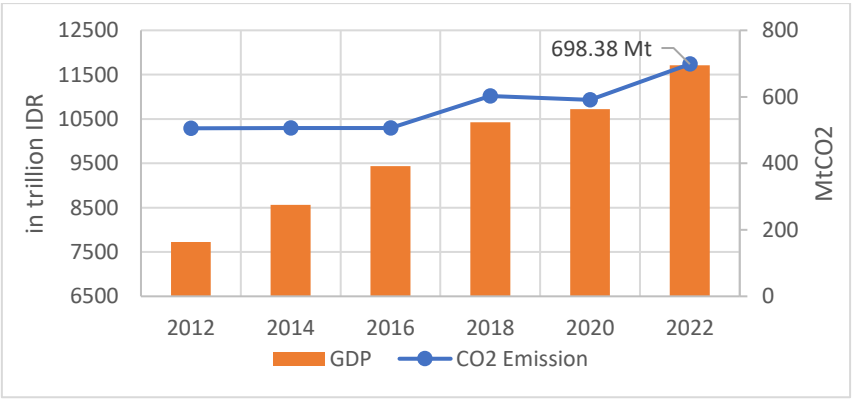


Figure 2. Gdp And Co2 Emissions In Indonesia Changed From 2012-2022 (Source: Author Processed (Badan Pusat Statistik, 2023; Crippa Et Al., 2022))

Although the EKC hypothesis posits a potential turning point where higher GDP can reduce environmental damage, its applicability to Indonesia remains uncertain. Several studies have examined the relationship between economic growth and emissions, the results of which have been inconclusive (Trianto and Purwanti, 2018; Prasetyanto and Sari, 2021; and Fajar and Hariyanto, 2021). Population dynamics, technological advances, and economic structure contribute to environmental challenges (Dietz & Rosa, 1997). FDI plays a dual role in influencing carbon emissions, with its impacts depending on the context and regulatory environment. While FDI can drive the adoption of clean technologies, it may also reinforce the Pollution Haven Hypothesis (PHH), where lax environmental regulations in developing countries attract polluting industries from developed nations. Research by Sabir et al. (2020) in South Asia found that FDI positively and significantly impacted CO_2 emissions in the short and long term, linking it to environmental degradation and resource depletion. In contrast, Abdouli et al. (2018) observed varying outcomes in BRICTS countries, with FDI correlating positively with Brazil, Russia, and China emissions, but showing the opposite effect elsewhere. These findings suggest that the environmental consequences of FDI are influenced by investor practices and local policies, highlighting the importance of balancing economic growth with sustainability to mitigate global greenhouse gas emissions. This study aims to measure and analyze the effect of gross domestic product (GDP) and Foreign Direct Investment (FDI) inflows on increasing carbon dioxide (CO2) emissions and to identify solutions to reduce environmental impacts. Given the variation of findings in previous studies, this topic is still a worthwhile area of research. This study examines the relationship between economic growth and environmental quality based on the Environmental Kuznets Curve (EKC) hypothesis. However, the study also considers the impact of other factors, namely FDI inflows.

LITERATURE REVIEW

Gross Domestic Product (GDP)

According to Badan Pusat Statistik (2023), GDP is the sum of the added value of final goods and services produced within a country in a year. It is one of the primary indicators of economic growth. The calculation of GDP employs three distinct approaches: production, which aggregates the added value of nine business sectors; income, which determines the returns to factors of production; and expenditure, which encompasses consumption, investment, government spending, and net exports (Badan Pusat Statistik, 2020). GDP values are presented using two methodologies: at current prices (ADHB), which reflects value added at current year prices, and at constant prices (ADHK), which employs a given year's prices to gauge economic growth in real terms from year to year.

Foreign Direct Investment Inflows

Foreign direct investment (FDI) inflows encompass foreign capital flows into domestic firms or projects. These flows include capital investment and management control (World Bank, 2019). Krugman et al. (2018) differentiate between vertical and horizontal foreign direct investment. The former capitalizes on differences in production costs, while the latter aims to bring production facilities closer to consumers. Dunning (in Rahayu & Pasaribu, 2017) Companies invest abroad for two main reasons: to obtain resources and sell to new customers. These goals are affected by politics, rules, and the ease of doing business (EODB). FDI entails capital inflows, technology transfer, and managerial expertise. The objective is to create a multiplier effect that boosts economic productivity and enhances the skill sets of the local workforce in the host country.

Air Pollution

Air pollution can be defined as the release of pollutants into the atmosphere that significantly degrade air quality and the environment (Simandjuntak, 2007). In Indonesia, the energy sector is the primary emitter of greenhouse gases (GHGs), followed by the industrial and trans-

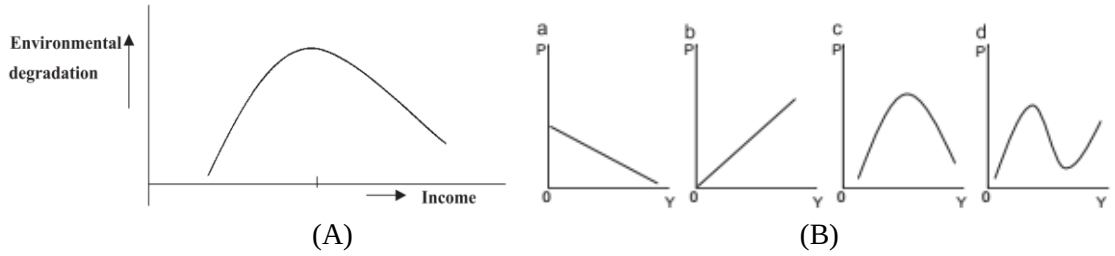
portation industries. This evidence suggests that human activities predominantly cause air pollution (Climate Transparency, 2022). GHGs are gases contributing to climate change and global warming. The Emissions Database for Global Atmospheric Research (EDGAR) classification (Crippa et al., 2022), the types of GHGs included carbon dioxide (CO2) from fossil fuel combustion, deforestation, and land use change; methane (CH4) from natural gas production, agriculture, and organic waste; nitrogen oxides (NOx) from fossil fuel combustion and industrial activities; fluorinated gases (HFCs, PFCs, SF6) used in industrial applications with high global warming potential; and ammonia (NH3) released from agricultural activities, particularly fertilizer use.

Externalities

An externality is the impact of an action that other parties feel without compensation from the party acting (Fauzi, 2010). Economic activities that cause environmental damage, such as CO2 emissions, can be categorized as negative externalities. This concept relates to public goods, where damage to the air environment reflects a conflict of interest over the ownership of public goods. According to Pigou and Coase (in Kiesling, 2021), government intervention is necessary to manage externalities because the government better understands the market's benefits and costs. With the right public policy, externalities can be minimized by efficiently allocating resources, and society can achieve the maximum benefit.

Environmental Kuznets Curve (EKC)

Grossman & Krueger (1991) introduced the Environmental Kuznets Curve (EKC) hypothesis. It describes the relationship between economic growth and a country's environmental quality changes. At first, economic growth ignores environmental damage. However, when income levels reach a certain point, called the turning point, public awareness of the need for a clean environment increases, leading to the adoption of pro-environmental policies and cleaner technologies. In the phase after the turning point, economic growth focuses on improving living standards and adopting environmentally friendly lifestyles. Thus, environmental degradation at the beginning of growth is followed by environmental improvement at the high-income stage (Dinda, 2004). However, Orubu and Omotor (2011) note that the shape of the EKC curve is not always an inverted U. There are several alternative EKC curve shapes that reflect different environmental and economic dynamics. This highlights that the economic and environmental relationship depends on contextual factors such as policy, technology, and public awareness.



(A) (B)

Figure 3. (A) Ekc Curve Model And (B) Alternative Forms Of Ekc Curves (Source: Dinda, 2004; Orubu And Omotor, 2011)

Pollution Haven Hypothesis (PHH)

The Pollution Haven Hypothesis (PHH) postulates that polluting industries tend to relocate their production to countries with weak environmental regulations. A case study of NAFTA conducted by Copeland and Taylor (1994) investigated the correlation between the stringency of environmental laws and trade patterns on pollution levels in a country. The findings indicated that trade liberalization could facilitate the relocation of polluting industries from developed countries with stringent environmental regulations to developing countries with less rigorous regulations.

This phenomenon contributes to developing countries becoming "pollution havens" for enterprises engaged in pollution-intensive activities. Moreover, Copeland and Taylor (1994) say that higher consumption in developed countries can boost industrial output in developing countries, which may lead to higher pollution. Gill et al. (2018) posit that for global pollution control to be effective, developed countries must reduce their consumption of polluting goods.

The Relationship between GDP and CO2 Emissions

The growth in production and demands for increased output result in greater use of natural resources and increased pollution intensity as waste. Consequently, there is a positive linear relationship between GDP and environmental damage, particularly in the form of CO2 emissions. Malthus's population theory (subsequently refined into the Ehrlich Model) elucidates the constant increase in population growth, which in turn precipitates an increase in resource demand (Hussen, 2004)The surge in resource demand leads to environmental degradation due to the increase in per capita consumption and the proliferation of products that are detrimental to the environment.

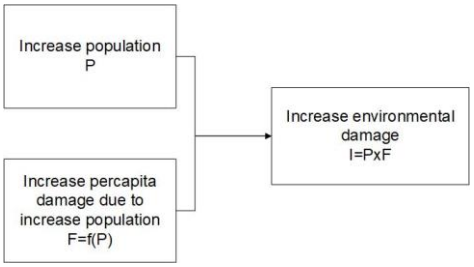


Figure 4. Ehrlich Model (Source: Hussen (2004)

Furthermore, elevated living standards in developed countries have resulted in increased consumption. Although their population comprises less than a third of the global population, these countries can allocate nearly 80% of the available resources (Todaro and Smith, 2011). The research conducted by Trianto and Purwanti (2018) and Fajar and Hariyanto (2021), which employed GDP variables, yielded a positive linear relationship, and substantiated the existence of the EKC hypothesis in Indonesia. In other developing countries, Gani (2012) the correlation between CO2 emissions and GDP was significant and positive when the variables were analyzed separately for the agricultural and industrial sectors. Bui Minh et al. (2023) also demonstrated bidirectional causality between CO2 emissions and GDP in Vietnam in both the short and long term.

The Relationship between FDI Inflows and CO2 Emissions

In developing countries, foreign direct investment (FDI) is regarded as a catalyst for economic growth, as it creates employment opportunities, facilitates the transfer of technology, and enhances productivity. However, despite its benefits, FDI inflows adversely affect the host countries. Several researchers have examined the relationship between FDI inflows and CO2 emissions. Abdouli et al. (2018) investigated this relationship in the BRICTS countries while Sabir et al.,(2020) focused on South Asia, and Bui Minh et al. (2023) explored the situation in Vietnam. The findings of these studies were only partially consistent, suggesting that management practices and access to green technology may vary across developing countries.

Research Framework

This study examines environmental degradation, focusing on rising CO2 emissions driven by GDP and FDI inflows. The increase in carbon dioxide emissions associated with GDP can be attributed to the prevalence of intensive economic activities that generate CO2 emissions. Additionally, the role of FDI inflows is significant as foreign investment can influence a country's production patterns. EKC theory offers a compelling theoretical foundation in alignment with the

abovementioned arguments. It posits that, alongside economic growth, a threshold exists at which the level of environmental damage reaches its peak and subsequently begins to decline. Integrating EKC theory can assist in elucidating whether a comparable pattern exists in the relationship between GDP and FDI inflows and carbon dioxide emissions.

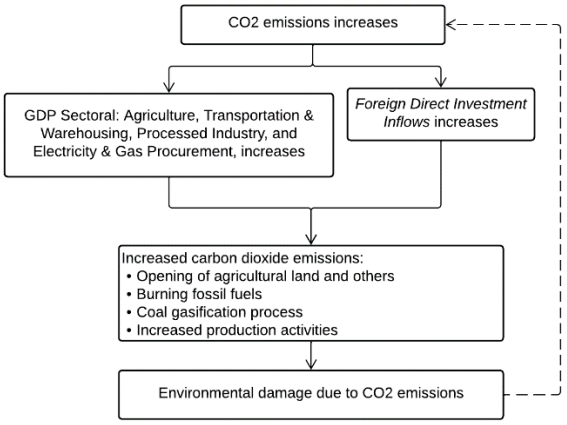


Figure 5. Research Framework (Source: Author, 2024)

METHOD

This study uses descriptive and quantitative methods to examine how GDP and FDI affect CO2 emissions, an indicator of environmental degradation in Indonesia. This study uses secondary data from 2002 to 2022. Sources include the Central Bureau of Statistics (BPS), the World Bank, the Emissions Database for Global Atmospheric Research (EDGAR), and the Indonesia Investment Coordinating Board (BKPM). Furthermore, all raw data used a Rupiah unit and was transformed into a natural logarithm for a straightforward interpretation. An Error Correction Model (ECM) with EViews 13 software was used for analysis. The ECM applies only to time series data exhibiting nonstationary and cointegration. To support the EKC hypothesis, we used a polynomial function as follows:

$$\mathbf{DCO2_t = \beta 0 + \beta 1 DPDB_t + \beta 2 DPDB2_t + \beta 3 DFDI_t + \beta 5 ECT_{t-1} + \mu_t}$$

Description:

DCO2	= Economic value of CO2 emissions
DPDB	= Accumulated GDP value of 4 business sectors
DPDB2	= Quadratic form of DPDB variable
DFDI	= Value of FDI Inflows
ECT	= Error Correction Term in the previous period

Then, to estimate the validity of the EKC hypothesis in Indonesia, it is based on:

a. If $\beta 2 < 0$, there is an inverted U-curve relationship
b. If $\beta 2 \geq 0$, there is a U-curve relationship
c. Turning point = $\frac{-\beta 1}{2\beta 2}$

Before regression testing, researchers must perform statistical tests, such as unit root, cointegration, and classical assumption tests. The latter comprises four tests: normality, heteroscedasticity, autocorrelation, and multicollinearity. As this study employs a polynomial regression model between GDP and GDP2, the requirement of freedom from multicollinearity is not a concern (Gujarati, 2006).

RESULTS AND DISCUSSION

Unit Root Test

The unit root test results for all variables indicate that the data is not stationary at the level. This is due to the pattern of increase over time, which affects both the average and the variance. At the 1st difference level test, the CO2 and the independent variables GDP and GDP2 show a stationary P-value, while the FDI variable does not. Consequently, the unit root test is continued to the 2nd difference level to ensure the stationarity of all variables.

Table 1. Unit Root Test Result

Variable	1st Diff		2nd Diff	
	T-Stat	P-Value	T-Stat	P-Value
CO2	-5.898893	0.0002**	-6.191838	0.0001**
PDB	-4.319196	0.0036**	-6.946917	0.0000**
PDB2	-4.321694	0.0036**	-6.944368	0.0000**
FDI	-1.959492	0.2996	-4.180192	0.0066**

Notes: **stationary at 5% level; *stationary at 10% level
Source: Author Processed, 2024

Cointegration Test

The cointegration test results on the residuals yield an error correction term (ECT) variable. The ECT variable exhibits a t-statistic value exceeding the 5% significance level with a stationary probability value (Prob. 0.0013). Therefore, it can be concluded that the equation exhibits cointegration in both the short and long run and meets the criteria for ECM modeling.

Long Term Regression Results (OLS)

Table 2 illustrates that the long-term regression test results indicate a negative correlation between GDP and CO2 emissions, with a coefficient of -5.937013. This implies that a 1% increase in GDP is associated with a 5.93% decline in CO2 emissions. In contrast, GDP2 has a positive effect, with a coefficient of 0.211332. Thus, a 1% increase in GDP2 results in a rise of 0.21% in CO2 emissions. The FDI variable also has a positive effect, with a coefficient of 0.116665. This indicates that a 1% increase in FDI results in a 0.11% increase in CO2 emissions. All three variables have a statistically significant effect at $\alpha = 5\%$ on CO2 emissions in Indonesia in the long run.

Table 2. Regression Results

Long Term (OLS)			Short Term (ECM)		
Variable	**Coefficient**	**Prob.**	**Variable**	**Coefficient**	**Prob.**
PDB	-5.937013	0.0096	D(PDB,2)	-27.69642	0.0075
PDB2	0.211332	0.0083	D(PDB2,2)	0.968273	0.0075
FDI	0.116665	0.0047	D(FDI,2)	0.019504	0.4331
C	55.77408	0.0014	ECT (-1)	-0.830053	0.0133
R-squared	0.937939		C	-0.007515	0.5644
Adj. R-squared	0.926987		R-squared	0.633949	
F-statistic	85.64184		Adj. R-squared	0.529364	
Prob(F-statistic)	0.000000		F-statistic	6.061522	

	Prob(F-statistic)	0.004788

Source: Author Processed, 2024

The equation is as follows:
CO2 = 55.77408 - 5.937013*PDB + 0.211332*PDB2+ 0.116665*FDI

The coefficient of determination (R-squared) of 93.79% indicates that most of the variation in CO2 emissions can be explained by the independent variables in the research model. At the same time, the remainder is influenced by other factors. The F-test, with a value of 85.64184 and a probability of 0.0000, indicates that GDP, GDP², and FDI have a significant simultaneous effect on CO2 emissions.

Short Term Regression Results (ECM)

The results of the short-term equation estimation in Table 2 indicate that the GDP variable exerts a significant negative influence on CO2 emissions, with a coefficient value of -27.69642. This means that a 1% increase in GDP will result in a 27.69% reduction in CO2 emissions. Conversely, the GDP2 variable positively and significantly affects CO2 emissions, with a coefficient of 0.968273. Thus, a 1% increase in the value of GDP2 will result in a 0.96% increase in CO2 emissions. Concerning the FDI variable, in the short term, it does not significantly affect CO2 emissions in Indonesia. The equation is as follows:
D (CO2,2) = - 0.007515 - 27.69642*D(PDB,2) + 0.968273*D(PDB2,2) + 0.019504*D(FDI,2) - 0.830053*ECT (-1)

In the ECM method, the model is deemed valid if the probability of the ECT (Error Correction Term) regression coefficient is statistically significant or more minor than α = 5%. As illustrated in the table above, the probability of the ECT coefficient is 0.0133, which is less than α = 5%. Consequently, it can be concluded that this model is valid. Subsequently, the coefficient of determination in the ECM model of 0.633949 indicates that the independent variables in the model can explain 63% of changes in CO2 emissions. The F-statistic value is 6.061522, greater than 5%, and Prob. 0.004788. Therefore, it can be concluded that all independent variables simultaneously affect the dependent variable.

The Effect of Gross Domestic Product on Carbon Dioxide Emissions in Indonesia

The relationship between sectoral gross domestic product (GDP) and CO2 emissions in Indonesia is characterized by intricate dynamics. As a nation that has ratified the Kyoto Protocol and the Paris Agreement, Indonesia faces considerable challenges in balancing economic growth and environmental sustainability (Kementerian Lingkungan Hidup dan Kehutanan, 2016). The relationship between sectoral GDP and CO2 emissions is typically positive. Nevertheless, this study's findings indicate a negative correlation between GDP and CO2 emissions in the short and long term. Conversely, the squared GDP variable has a positive and statistically significant effect on CO2 emissions. This indicates that an increase in sectoral GDP can reduce CO2 emissions during the initial stages of economic growth. Nevertheless, beyond a certain threshold, further growth in GDP is associated with an increase in CO2 emissions. This inconsistency indicates that the model estimation results must align with the Environmental Kuznets Curve (EKC) hypothesis despite the statistical significance of both variables concerning CO2 emissions. A comparable phenomenon was also observed in Sugiawan and Managi (2016) study, which was attributed to multicollinearity in the model.

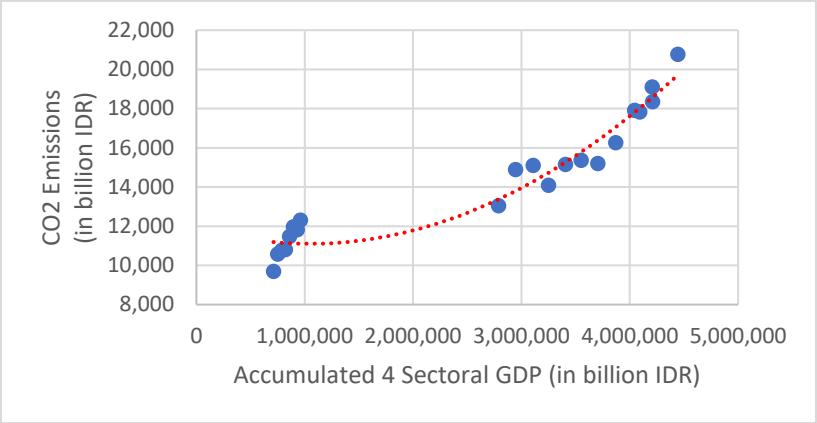


Figure 6. Scatter Plot Between Pdb and Co2 Emissions
(Source: Author Processed, 2024)

The model estimation results indicate a U-shaped relationship between sectoral GDP and CO2 emissions. In the initial phase, an increase in sectoral GDP contribution will decrease CO2 emissions, both in the short and long term, assuming all other variables remain constant. However, once sectoral GDP reaches Rp1,626,433.27 billion in the short term, CO2 emissions will increase by 0.97%. In the long run, after sectoral GDP reaches Rp1,260,034.11 billion, CO2 emissions will increase by 0.21%. The turning points in both models are calculated by identifying the extreme point of the model ($\frac{-\beta 1}{2\beta 2}$) and then transforming it into exponential form. The discrepancy in the results of this test indicates that endeavours to enhance economic output may still result in diminished environmental quality, particularly in terms of air quality. Despite Indonesia's status as one of the leading CO2 emitters globally, this outcome is incongruent with anticipated sustainability initiatives.

The Effect of Foreign Direct Investment Inflows on Carbon Dioxide Emissions in Indonesia

Foreign direct investment (FDI) plays a significant role in the economy, particularly in developing countries like Indonesia. FDI fosters increased output and job creation, prompting the government to implement policy deregulation (Ciptaker Law), energy tariff reductions, and tax incentives to facilitate the entry of foreign investment. However, an uptick in FDI can also give rise to adverse effects, such as an uptick in CO2 emissions, which presents a challenge. The results of this study indicate that FDI inflows positively influence CO2 emissions in Indonesia, although the effect is not statistically significant in the short term. This finding is consistent with the findings of Abdouli et al. (2018) in Russia and China and Sarkodie and Strezov (2019), who identified a U-shaped relationship between FDI inflows and CO2 emissions. Similarly, Sabir et al. (2020) identified a comparable pattern in South Asian countries. Indonesia's pronounced long-term impact on FDI is likely attributable to the preponderance of FDI flows to the secondary sector over the past decade.

As indicated in the Climate Transparency report (2022), 71% of Indonesia's energy mix continues to be derived from fossil fuels, with the industrial sector representing the primary energy consumer. The rising share of coal in the energy mix, which continues to increase annually, is accompanied by increased CO2 emissions alongside economic activity. Abdouli et al. (2018) also identified a negative environmental impact resulting from foreign investors' need for more adoption of clean technologies. As a developing country, Indonesia exhibits the characteristics associated with the Pollution Haven Hypothesis (PHH). Despite its relatively low per capita CO2 emissions (2.6 tCO2/capita), Indonesia's total emissions are considerable, ranking 7th globally (Crippa et al., 2022). Evidence suggests that economic sectors receiving foreign direct investment (FDI) exploit the lack of robust environmental regulations to reduce production costs, thereby

contributing to Indonesia's status as a "pollution haven." Furthermore, implementing green technologies in developing countries necessitates a considerable investment of time and resources. However, studies conducted in Turkey (Öztürk and Öz, 2016) and Algeria (Udemba and Yalçıntaş, 2021) have yielded contradictory results, indicating a negative relationship between FDI and CO2 emissions. This discrepancy in findings may be attributed to variations in economic structures, research methodologies, and other contributing factors. Additional research is essential to elucidate the underlying mechanisms behind this phenomenon.

The Consequences of Increased CO2 Emissions in Indonesia

The increased CO2 emissions in Indonesia result from two key factors: rapid economic growth and the influx of foreign direct investment (FDI). While these two factors provide significant economic benefits, the negative environmental impacts, particularly increased CO2 emissions, must be addressed. The industrial sector, especially those based on fossil energy, and the transportation sector contribute significantly to this increase in emissions. The rise in the production and number of motor vehicles fuels the growth of these sectors. Foreign direct investment (FDI) inflows exert an ambivalent influence on CO2 emissions. On the one hand, FDI introduces more efficient and environmentally friendly technologies and management practices. However, government policies, such as energy subsidies for the industrial sector, increase fossil energy consumption. Research by Sasana et al. (2018) demonstrates that this energy subsidy policy significantly elevates fossil energy consumption, which raises social costs, including expenditures on addressing air pollution-related diseases, such as lung disease and dengue fever.

Indonesia has the highest air pollution in Southeast Asia, with PM2.5 levels that exceed the World Health Organization's (WHO) safe limit by a significant margin (IQAir, 2023). Air pollution substantially contributes to the prevalence of respiratory diseases, particularly in urban areas. The Ministry of Health's budget for respiratory disease prevention increased between 2018 and 2022, with air pollution identified as a key risk factor for lung disease, accounting for 15-30% of the total risk factors (Redaksi Sehat Negeriku, 2023). Additionally, high CO2 emissions have a detrimental impact on the global climate, leading to rising temperatures, altered rainfall patterns, and an increased frequency of floods and droughts. Since the 1980s, Indonesia has experienced an average temperature increase of 0.45°-0.75°C per decade, attributed to greenhouse gas emissions. As outlined in the Climate Resilience Development Policy publication (Bappenas, 2021), climate change exerts a direct influence on the agricultural, fisheries, and food security sectors, leading to a reduction in productivity, an elevated risk of crop failure, and the deterioration of infrastructure due to natural disasters. Furthermore, marine and coastal ecosystems are also threatened, endangering the livelihoods of fishermen and the sustainability of marine resources. Collectively, these factors can result in significant economic losses and impede development.

Solutions to Increased Carbon Dioxide Emissions in Indonesia

Indonesia remains significantly reliant on fossil fuels, including coal and petroleum, major contributors to CO2 emissions. While sectoral GDP has been observed to affect CO2 emissions negatively, the emergence of positive GDP_2 estimates warrants close observation. The issue of climate change due to CO2 emissions has become a significant concern, and several policy scenarios to address this have been developed by the World Bank (2023a) in the Indonesia Country Climate and Development Report (CCDR). These policies include decarbonizing the energy sector, restoring peatlands, and implementing a carbon tax. In addition to the World Bank, the Indonesian government also seeks to implement various policies to reduce CO2 emissions. One such policy is OJK regulation (POJK) No.51/POJK.03/2017, which requires companies to prepare sustainability reports to increase transparency and accountability in managing environmental risks. Furthermore, implementing a carbon tax on high-emission sectors, including fossil fuel power plants and the transportation sector, which the Taxation Harmonization Law regulates, has also been gradually introduced since April 2022. In the future, a cap-and-trade mechanism will also be part of the policy to reduce emissions. This mechanism will allow industry players that produce emissions below a specified limit to sell their emission quota. Revenue from carbon taxes and

trading will be allocated to fund climate change mitigation and adaptation programs, including investments in renewable energy and energy efficiency. Moreover, the government is encouraging investment in renewable energy sectors, such as solar, wind, and geothermal, to reduce dependence on fossil fuels and create jobs.

In light of the experiences of neighbouring countries, implementing pro-environmental policies, such as the imposition of progressive taxes on old motor vehicles in Singapore, can also be an effective solution. Furthermore, Singapore permits its residents to exchange aged vehicles for more efficient and environmentally friendly ones, encouraging the utilization of environmentally friendly vehicles (Land Transport Authority Singapore, 2024). In Malaysia, the implementation of Euro 5 emission standards for motor vehicles, which commenced in April 2021, is designed to reduce pollutants such as sulfur dioxide and can potentially reduce CO2 emissions (Department of Environment Malaysia, 2021). In summary, the Indonesian government's policies in the current economic sector demonstrate a robust commitment to addressing rising CO2 emissions. By strengthening industry regulation, implementing carbon taxes, and increasing investment in renewable energy, the government is not only striving to meet national emission reduction targets. Still, it is also promoting more sustainable economic development. Notably, the government is also considering the successful policy options of other countries, which could provide a practical approach to reducing CO2 emissions. If implemented effectively, these measures could bring Indonesia closer to a greener and cleaner future.

CONCLUSION AND SUGGESTIONS

Conclusion

In light of the research conducted and the preceding analysis, the following conclusions may be drawn:

1. The sectoral GDP variable (accumulation of four business sectors) negatively and significantly affects CO2 emissions in both the long and short term. However, the square of the sectoral GDP variable positively affects CO2 emissions in both periods. This abnormal finding suggests that efforts to increase economic output still ignore the impact on CO2 emissions. An increase in living standards followed by consumerism means that even though GDP has reached an optimal point, production activities need to be more efficient regarding energy use.
2. The value of FDI inflows positively and significantly affect CO2 emissions in the long run. The increase in the line between the two indicates that incoming investment is still focused on economic sectors that drive up energy consumption and industries that still need to adopt environmentally friendly technology.
3. The EKC hypothesis has yet to be proven in Indonesia. While sectoral GDP and its squared form are statistically significant, the coefficients' sign does not align with the EKC hypothesis's requirements. Consequently, the inverted U-curve has yet to be identified in the long-run or short-run models.
4. Regarding the consequences that arise, the government can implement the following solutions: It can immediately create derivative policy instruments regarding the implementation of carbon taxes and trading, encourage the development of the renewable energy sector, and consider applying other countries' policies that have succeeded in providing practical approaches to reducing CO2 emissions.

Suggestion

In terms of efforts to mitigate the effects of climate change, implementing environmentally friendly technology and efficiency measures within the industrial sector effectively reduces carbon dioxide emissions. Furthermore, the author recommends investigating additional independent variables influencing CO2 emissions in Indonesia to address this study's limitations. Using diverse analytical tools and research models and examining study locations at varying levels of scope can facilitate a more comprehensive and accurate understanding of the evidence supporting the EKC hypothesis in Indonesia.

LIMITATIONS

The present study will focus on a limited number of independent variables to facilitate discussion of the Environmental Kuznets Curve (EKC). These variables are as follows: The research will examine the relationship between GDP and carbon dioxide emissions in Indonesia. This will entail the analysis of the GDP variables over four business sectors (agriculture, transportation and warehousing, processing industry, and electricity and gas procurement). In addition, the study will investigate the squared form of GDP over the business sectors in question. The value of FDI inflows, too, will be considered. The indicator of increased environmental damage will focus on carbon dioxide emissions. These will be expressed in economic terms.

REFERENCES

Abdouli, M., Kamoun, O., Hamdi, B., Chandran, V. G. R., Tang, C. F., Sabir, S., Qayyum, U., & Majeed, T. (2018). The Impacts of Transport Energy Consumption, Foreign Direct Investment and Income on CO2 Emissions in ASEAN-5 Economies. *Renewable and Sustainable Energy Reviews*, *27*(4), 445–453. DOI: 10.1007/s11356-020-09464-y.

Badan Pusat Statistik. (2020). *Ringkasan Metadata Statistik Dasar 2019*. Accessed from https://www.bps.go.id/id/publication/2020/03/24/f399f2c6d64ea0d792ad5fa4/ringkasan-metadata-statistik-dasar-2019.

Badan Pusat Statistik. (2023). *Produk Domestik Bruto atas Lapangan Usaha*. Accessed from https://www.bps.go.id/subject/11/produk-domestik-bruto--lapangan-usaha-.html#subjekViewTab2.

Bappenas. (2021). *Executive-Summary Climate Resilience Development Policy 2020-2045*. Accessed from https://lcdi-indonesia.id/wp-content/uploads/2021/11/0_Executive-Summary.pdf.

Bappenas. (2023). *Ringkasan Rencana Kerja Pemerintah Tahun 2023*. Accessed from https://perpustakaan.bappenas.go.id/e-library/file_upload/koleksi

Bui Minh, T., Nguyen Ngoc, T., & Bui Van, H. (2023). Relationship between Carbon Emissions, Economic Growth, Renewable Energy Consumption, Foreign Direct Investment, and Urban Population in Vietnam. *Heliyon*, *9*(6). DOI: 10.1016/j.heliyon.2023.e17544.

Climate Transparency. (2022). *Indonesia Climate Transparency Report: Comparing G20 Climate Action*. Accessed from https://www.climate-transparency.org/wp-content/uploads/2022/10/CT2022-Indonesia-Web.pdf

Copeland, B. R., & Taylor, M. S. (1994). North-South Trade and the Environment. *The Quarterly Journal of Economics*, *109*(3), 755–787. Accessed from http://www.jstor.org/stable/2118421.

Crippa, M., Guizzardi, D., Banja, M., Solazzo, E., Muntean, M., Schaaf, E., Pagani F., Monforti-Ferrario, F., Olivier, J. G. J., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Grassi, G., Rossi, S., Oom, D., Branco, A., San-Miguel, J., Vignati, E., & European Commission. Joint Research Centre. (2022). *CO2 emissions of all world countries : JRC/IEA/PBL 2022 Report*. European Commission. DOI: 10.2760/07904.

Department of Environment Malaysia. (2021). *Implementation of Euro 5 Diesel Oil Specification*. Department of Environment, Ministry of Natural Resources And Environmental Sustainability. Accessed from https://www.doe.gov.my/en/2021/10/26/implementation-of-euro-5-diesel-oil-specification-starts-on-april-1-2021/

Dietz, T., & Rosa, E. A. (1997). Effects of Population and Affluence on CO2 Emissions. *Proceedings of the National Academy of Sciences of the United States of America*, *94*(1), 175–179. DOI: 10.1073/pnas.94.1.175.

Dinda, S. (2004). *Environmental Kuznets Curve Hypothesis : A Survey*. *49*, 431–455. DOI: 10.1016/j.ecolecon.2004.02.011.

Fajar, M., & Hariyanto. (2021). Pengujian Eksistensi Environmental Kuznets Curve di Indonesia. *Jurnal Lebesgue : Jurnal Ilmiah Pendidikan Matematika, Matematika Dan Statistika*, *2*(1), 62–68. DOI: 10.46306/lb.v2i1.56.

Fauzi, A. (2010). *Ekonomi Sumber Daya Alam dan Lingkungan*. Jakarta. Gramedia Pustaka

Utama.
Gani, A. (2012). The Relationship Between Good Governance and Carbon Dioxide Emissions: Evidence From Developing Economies. *Journal of Economic Development*, *37*(1), 77–93. DOI: 10.35866/caujed.2012.37.1.004.
Gill, F. L., Viswanathan, K. K., & Karim, M. Z. A. (2018). The Critical Review of The Pollution Haven Hypothesis. *International Journal of Energy Economics and Policy*, *8*(1), 167–174. Accessed from https://www.econjournals.com/index.php/ijeep/article/view/5678
Grossman, G. M., & Krueger, A. B. (1991). *Environmental Impacts of A North American Free Trade Agreement* (3914; Issue 3914). DOI: 10.3386/w3914.
Gujarati, D. N. (2006). *Dasar-dasar Ekonometrika Jilid 1* (5th ed.). Jakarta. Penerbit Erlangga.
Hussen, A. M. (2004). Principles of Environmental Economics. In *Principles of Environmental Economics* (2nd Edition). Taylor & Francis e-Library. DOI: 10.4324/9780203507421.
IQAir. (2023). World Air Quality Report 2023. In *IQAir*. Accessed from https://www.iqair.com/id/world-most-polluted-countries
Kementerian Investasi/BKPM. (2020). *Realisasi Penanaman Modal*. www.bkpm.go.id
Kementerian Lingkungan Hidup dan Kehutanan. (2016). *Indonesia Menandatangani Perjanjian Paris Tentang Perubahan Iklim*. Siaran Pers Humas KemenLHK. Accessed from https://ppid.menlhk.go.id/siaran_pers/browse/298#:~:text=Negara-negara dengan tingkat emisi,negara pertama yang melakukan ratifikasi.
Kiesling, L. (2021). *The Essential Ronald Coase*. Fraser Institute. DOI: 10.4324/9780429022654-4.
Krugman, P. R., Obstfeld, M., & Melitz, M. J. (2018). *International Trade Theory and Policy* (11th ed.). Pearson. Accessed from www.pearsonglobaleditions.com
Land Transport Authority Singapore. (2024). *Road Tax*. One Motoring. Accessed from https://onemotoring.lta.gov.sg/content/onemotoring/home/owning/ongoing-car-costs/road-tax.html.
Orubu, C. O., & Omotor, D. G. (2011). Environmental Quality and Economic Growth: Searching for Environmental Kuznets Curves for Air and Water Pollutants in Africa. *Energy Policy*, *39*(7), 4178–4188. DOI: 10.1016/j.enpol.2011.04.025.
Öztürk, Z., & Öz, D. (2016). The Relationship between Energy Consumption, Income, Foreign Direct Investment, and CO2 Emissions: The Case of Turkey. *Cankiri Karatekin Universitesi Iktisadi ve Idari Bilimler Fakultesi Dergisi*, *6*(2), 269–288. DOI: 10.18074/cnuiibf.461.
Prasetyanto, P. K., & Sari, F. (2021). Environmental Kuznets Curve: Economic Growth with Environmental Degradation in Indonesia. *International Journal of Energy Economics and Policy*, *11*(5), 622–628. DOI: 10.32479/IJEEP.11609.
Rahayu, I. T., & Pasaribu, E. (2017). Faktor-Faktor yang Memengaruhi Foerign Direct Investment (FDI) di Enam Koridor Ekonomi Indonesia: Market Seeking atau Resource Seeking? *Jurnal Aplikasi Statistika & Komputasi Statistik*, *9*(1), 31–40. DOI: 10.34123/jurnalasks.v9i1.92.
Redaksi Sehat Negeriku. (2023). *Polusi Udara Sebabkan Angka Penyakit Respirasi Tinggi*. Kementerian Kesehatan. Accessed from https://sehatnegeriku.kemkes.go.id/baca/rilis-media/20230404/2642721/polusi-udara-sebabkan-angka-penyakit-respirasi-tinggi/
Sabir, S., Qayyum, U., & Majeed, T. (2020). FDI and Environmental Degradation: The Role of Political Institutions in South Asian Countries. *Environmental Science and Pollution Research*, *27*(26), 32544–32553. DOI: 10.1007/s11356-020-09464-y.
Sarkodie, S. A., & Strezov, V. (2019). Effect of Foreign Direct Investments, Economic Development and Energy Consumption on Greenhouse Gas Emissions in Developing Countries. Science of the Total Environment. *Science of the Total Environment*, *646*, 862–871. DOI: 10.1016/j.scitotenv.2018.07.365.
Sasana, H., Salman, F., Suharnomo, S., Nugroho, S. B. M., & Yusuf, A. G. E. (2018). The Impact of Fossil Energy Subsidies on Social Cost in Indonesia. *International Journal of Energy Economics and Policy*, *8*(2), 168–173. Accessed from

https://www.econjournals.com/index.php/ijeep/article/view/6162
Simandjuntak, A. G. (2007). Pencemaran Udara. *Buletin Limbah*, *11*(1), 34–40.
Sugiawan, Y., & Managi, S. (2016). The Environmental Kuznets Curve in Indonesia: Exploring The Potential of Renewable Energy. *Energy Policy*, *98*, 187–198. DOI: 10.1016/j.enpol.2016.08.029.
Todaro, M. P., & Smith, S. C. (2011). *Pembangunan Ekonomi* (11th ed.). Penerbit Erlangga.
Trianto, M. F. S., & Purwanti, E. Y. (2018). Pertumbuhan Penduduk, Inflasi dan Korupsi: Analisis Empiris Environmental Kuznets Curve (EKC) di Kawasan Asean Periode 2002-2016. *Jurnal Dinamika Ekonomi Pembangunan*, *1*(3), 71–81. DOI: 10.14710/jdep.1.3.71-81.
Udemba, E. N., & Yalçıntaş, S. (2021). Interacting Force of Foreign Direct Invest (FDI), Natural Resource and Economic Growth in Determining Environmental Performance: A Nonlinear Autoregressive Distributed Lag (NARDL) Approach. *Resources Policy*, *73*. DOI: 10.1016/j.resourpol.2021.102168.
World Bank. (2019). *FDI Inflows Net (BoP current US$)*. World Bank. Accessed from https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD?locations=ID
World Bank. (2023a). Indonesia Country Climate and Development Report. In *World Bank Group*. DOI: 10.1596/978-1-4648-0484-7_world_bank_group.
World Bank. (2023b). *GDP (constant 2015 US$)*. Accessed from https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?locations=ID-MY-SG-TH-VN-LA-BN-PH-MM-KH