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Economic Development and Fiscal Policy in CO2 Emission Mitigation: A Dynamic Panel Study in Indonesia Before Covid 19

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ABSTRACT

This study aims to analyze the impact of economic development and fiscal policy on CO2 emissions in Indonesia. Using a time series data from 2009 to 2019 covering 20 provinces in Indonesia before the COVID-19 pandemic, this study analyzed data with a dynamic panel approach. The results show that in the short term, Gross Regional Domestic Product (GDP) and population have a negative influence on CO2 emissions, while in the long term, GDP and population have a positive effect on CO2 emissions. The Central to Regional Transfer Fund (DAU) shows a positive effect on CO2 emissions in the short term but has a negative effect in the long term. Spending on education has a negative effect on CO2 emissions in the short term, while in the long term, it has no significant effect. Spending on health has shown no effect on CO2 emissions in either the short or long term. Foreign Direct Investment (FDI) has a negative effect on CO2 emissions in both periods. Based on these findings, the policy that needs to be considered in the future is to strengthen the policy of transferring Central Transfer Funds to Regions that better supports environmentally friendly initiatives, as well as encourage foreign investment oriented towards green and sustainable technology. In addition, the allocation of funds for the education sector can be prioritized for the development of policies that support the reduction of CO2 emissions, while health spending can be directed to programs that integrate economic growth with environmental sustainability.

Keywords: CO2 Emissions, Dynamic Panel, Fiscal Policy, Economic Growth

1. INTRODUCTION

Economic growth and fiscal policy are two interrelated factors in controlling CO_2 emissions, a crucial issue in global climate change mitigation efforts (Abid, 2016; Dauda, et al., 2019). In Indonesia, rapid economic growth is often followed by increased energy consumption, which has an impact on high greenhouse gas emissions. This suggests that there is a complex relationship between economic development, fiscal policy, and CO_2 emissions that needs to be further analyzed.

Economic growth theory states that higher increases in gross domestic product (GDP) are associated with increased energy consumption and greenhouse gas emissions, including CO_2. An increase in GDP usually occurs in tandem with an increase in economic activity, which has the potential to increase the use of fossil energy and CO_2 emissions (Schandl, et al., 2016). This is expressed in the Environmental Kuznets Curve (EKC) theory, which shows that CO_2 emissions tend to increase along with economic development initially but will decrease after reaching a certain income level due to increased energy efficiency and adoption of environmentally friendly technologies.

Fiscal policies, including government spending and tax revenues, play an important role in managing CO_2 emissions (Le & Ozturk, 2020). Fiscal spending directed towards green infrastructure development, or the development of low-emission technologies can reduce CO_2 emissions. In contrast, fiscal policies that place more emphasis on fossil energy subsidies or projects that rely on non-renewable resources could exacerbate emissions problems. In the Indonesian context, the General Allocation Fund (DAU) allocated for regional development can play a role in reducing emissions if used for environmentally friendly projects.

Environmental theory emphasizes the importance of emission control policies to achieve environmental sustainability. In this case, government spending on the education, health, and tax policies and environmental incentives can affect CO_2 emission levels. For example, spending in the education sector can increase public awareness of climate change issues and the importance of reducing emissions, while fiscal policies involving carbon taxes can encourage emission reductions through market mechanisms.

Economic growth reflected in GDP has two sides that can affect CO_2 emissions. On the one hand, an increase in GDP can lead to increased energy consumption and emissions. However, on the other hand, if economic growth is driven by more energy-efficient sectors or green technology sectors, then there can be a reduction in emissions. Previous research has shown that the influence of GDP on CO_2 emissions tends to be positive in the long term but may not be significant in the short term due to energy efficiency and still limited use of technology.

Government spending in the education sector can reduce CO_2 emissions by increasing public awareness of the importance of better environmental management. Health sector spending, while not directly related to emissions reductions, has an impact on social well-being that can influence policy decisions in the long run. Meanwhile, Foreign Direct Investment (FDI), especially those focused on green technology, can help reduce CO_2 emissions by bringing environmentally friendly technologies to Indonesia.

Several studies suggest that Gross Regional Domestic Product (GDP) can have a positive effect on CO_2 emissions in the long term because increased economic activity often leads to increased consumption of fossil energy (Suhrab, et al., 2023; Lyeonov, et al., 2019). On the other hand, population also has a significant influence on emissions, with an increase in population potentially increasing energy and transportation needs, which further increases CO_2 emissions.

However, fiscal policies such as the General Allocation Fund (DAU) and education sector spending can also have an influence on CO_2 emissions. More recent studies show that DAUs, allocated for regional development, can negatively affect CO_2

emissions in the long term as they encourage green and sustainable infrastructure development (Yan, et al., 2023). In contrast, education spending tends to reduce emissions in the short term, with increased awareness and understanding of climate change issues (Bangay & Blum, 2010).

However, not all sectors show a clear link to CO_2 emissions. For example, health sector spending in Indonesia does not show a significant impact on reducing CO_2 emissions, either in the short and long term (Akbar, et al., 2020). Similarly, although Foreign Direct Investment (FDI) can contribute to reducing CO_2 emissions through the application of green technologies, its impact remains dependent on the type of investment that enters developing countries such as Indonesia (Tariq, et al., 2022).

Studies comparing the long-term and short-term effects between GDP, population, and fiscal policy on CO_2 emissions are still limited (Aminata, et al., 2022; Kamal, et al., 2021). Most studies have focused only on long-term relationships, so the lack of understanding of short-term influences is still a significant gap. Many studies consider Indonesia as a unit, even though the impact of fiscal and economic policies on CO_2 emissions can differ from province to province (Busch, et al., 2012). Therefore, research analyzing influences at the regional or provincial level is still minimal and needs to be further developed.

Research on the impact of certain sectors such as manufacturing and transportation on CO_2 emissions under fiscal policy and economic growth has not been widely conducted. In fact, these sectors are the main contributors to emissions in Indonesia, and the influence of fiscal policy on these sectors needs to be analyzed more deeply (Ullah, et al., 2020). Many studies ignore the role of green technology and innovation in influencing the relationship between economic development, fiscal policy, and CO_2 emissions. In fact, the adoption of green technology can improve energy efficiency and reduce greenhouse gas emissions. Further research is needed to measure the extent to which technological innovation affects emissions reduction in Indonesia (Raihan, et al., 2022).

Research exploring the role of socioeconomic factors, such as income distribution and inequality, in the influence of fiscal policy on CO_2 emissions is still very limited. Fiscal policy not only impacts the economy but also affects individuals and groups in societies that have different capacities to adapt to climate change. This research also aims to explore the influence of fiscal policies, such as the General Allocation Fund (DAU), education, health spending, and Foreign Direct Investment (FDI) on CO_2 emissions. This research focuses on the influence of DAU in short- and long-term contexts and how education and health sector spending relate to emission reduction efforts.

This study provides stronger empirical evidence on the influence of fiscal and economic policies on CO_2 emissions in Indonesia, with a focus on DAU, education sector spending, health, and FDI. These findings could provide a clearer picture of the effectiveness of fiscal policies in reducing CO_2 emissions and how they can be tailored to regional needs. By identifying sectors that can contribute to reducing CO_2 emissions, the study can help policymakers formulate more specific and targeted programs to achieve emission reduction targets, as well as encourage the adoption of green technologies in various industrial sectors.

2. RESEARCH METHOD

To analyze the impact of economic development and fiscal policy on CO_2 emissions, a dynamic panel approach (Gujarati & Porter, 2009) was used on data from 2009-2019 in 20 provinces in Indonesia with an econometric equation model with the Dynamic Panel Data Model approach. In this model, a dynamic panel approach will be used that considers

time effects and individual (interprovincial) effects in explaining CO_2 emissions. This model considers the influence of independent variables such as GDP, population, DAU, education spending, health spending, and FDI on CO_2 emissions.
The econometric model used for this study can be derived as follows:

$$CO_{2it} = \alpha + \beta_1 CO_{2it-1} + \beta_2 PDRB_{it} + \beta_3 Pop_{it} + \beta_4 DAU_{it} + \beta_5 EDUC_{it} + \beta_6 Healt_{it} + \beta 7FDI_{it} + \lambda_t + \mu_i + \epsilon_{it}$$

Information:

$CO_{2\square i}$: CO_2 emissions in province i on waktu t.
$CO_{2\square -1i}$: CO_2 emissions in the province i at the time t-1.
$PDRB_{i\square}$: Gross Regional Domestic Product in the province i at the time t.
$Popi_{i\square}$: Population in the province i at the time t.
$DAU_{i\square}$: General Allocation Funds received by the province i at the time of the t.
$EDUC_{i\square}$: Expenditure for the education sector in the province i at the time t.
$HEALTH_{i\square}$: Expenditure for the health sector in the province i at the time t.
$FDI_{i\square}$: Foreign Direct Investment that enters the province i at the time t.
$\lambda_{\square}$: Time effects controlling influencing factors at the same time.
μ_i : Fixed effects of individuals controlling fixed characteristics that affect CO emissions₂.
$\varepsilon_{i\square}$: Term errors that affect dependent variables at time t and province i.

For the dynamic panel approach, there are two models that are often used, namely Fixed Effects Models and Random Effects Models. The stage of panel data analysis with VECM (Basuki & Prawoto, 2019) involves several important tests: stationarity test, lag length, stability test, and cointegration test. After that, the results of the VECM regression can be interpreted to identify the long-term relationships and short-term dynamics between variables. An in-depth understanding of each of these stages is essential to obtain valid and accurate results in the analysis of the VECM model.

3. RESULTS AND ANALYSIS

To perform panel data analysis with the Vector Error Correction Model (VECM) approach, several test stages must be performed first to ensure valid and accurate results. This stage involves testing stationarity, lag length, stability test, and cointegration test. Here is a detailed explanation of these stages:

Stationarity Test

Stationary data is data that has a constant meaning and variance over time and has no clear trends. Data that is not stationary (for example, has a variable trend or variance) can result in inconsistent estimates, and can lead to problems such as spurious regression. Therefore, stationarity tests need to be performed to ensure that the data is ready to be used in the VECM Panel model. The importance of stationarity tests in avoiding spurious regression in time series and panel models, as well as discussing the most frequently used test options (Zou, 2018). Stationarity test is performed using the PP - Fisher Chi-square unit root test: Used for panel data, testing whether variables in the panel data are stationary across cross-sections.

Table 1. Stationary Test

Method		Data Level			First Difference		
		Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square
ECO2	Stat	1.9612	13.2650	2.2915	-4.7977	100.6930	146.5640
	Prob	0.9751	1.0000	1.0000	0.0000	0.0000	0.0000
PDRB	Stat	2.3391	18.4004	149.7100	-11.1806	149.7480	99.0926
	Prob	0.9903	0.9986	0.0000	0.0000	0.0000	0.0000
POP	Stat	2.2410	20.0104	12.3020	-17.1517	228.6950	253.4000
	Prob	0.9875	0.9965	1.0000	0.0000	0.0000	0.0000
DAU	Stat	5.1658	5.3624	5.6366	-4.3960	95.4069	186.5850
	Prob	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000
EDUC	Stat	5.5540	6.9350	15.1909	-0.9221	44.6894	126.7590
	Prob	1.0000	1.0000	0.9999	0.1782	0.2813	0.0000
EDUC	Stat	1.7392	20.0585	38.3767	-4.9335	106.5040	211.6100
	Prob	0.9590	0.9964	0.5435	0.0000	0.0000	0.0000
EDUC	Stat	-6.6360	119.0750	82.2955	-5.3175	107.6130	211.9440
	Prob	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Obs		180	180	200	180	180	200

Source: Data processed (2023)

Based on the results of the stationary test for the level data in Table 1 seen from the probability value above 0.05, this result indicates that the data does not pass the stationary level data. So that a stationary test was carried out for the first derivative data. From Table 1 for the level data stationary test using the PP - Fisher Chi-square method, all data passed stationery.

Maximum Lag Length

The selection of lag length is an important stage in the analysis of the VECM Panel model. The length of the lag affects the dynamics of the model and the relationships between variables. The Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC) are used to select the optimal lag length. This criterion balances between the quality of the model and the number of parameters used.

Table 2. Maximum Lag Length
Endogenous variables D(LOG(ECO2)) D(LOG(PDRB)) D(LOG(POP)) D(LOG(DAU)) D(LOG(EDU)) D(LOG(HEALTH)) D(LOG(FDI))

Lag	LogL	LR	FPE	AIC	SC	HQ
0	376.9589	NA	2.31E-11	-4.62449	-4.489947*	-4.56985
1	467.7865	172.5726	1.37E-11	-5.14733	-4.07102	-4.71028
2	593.5115	227.8766*	5.28e-12*	-6.106394*	-4.08831	-5.286921*

* Indicates lag order selected by the criterion

Based on Table 2 the optimal lag length is at lag 2, because the Akaike Information Criterion (AIC) has a Star mark. Yang, et al (2022) explains that the selection of the right lag length is essential in dynamic models to avoid overfitting or underfitting. They also note that the use of AIC and SBC is common practice in panel research.

Stability Test

The VECM Panel model must be stable to ensure that the long-term relationships between variables remain convergent, and do not result in uncontrolled or divergent solutions (Lütkepohl & Krätzig, 2005). The Eigenvalue Test is used to test whether the VECM model is stable. All characteristic roots of the model must be within the circle of the root unit (the eigenvalue must be less than one) to ensure stability.

Tabel 3 Stability Test	
Root	Modulus
-0.490538 - 0.782662i	0.923681
-0.490538 + 0.782662i	0.923681
0.100145 - 0.726127i	0.733000
0.100145 + 0.726127i	0.733000
-0.454389 - 0.454444i	0.642642
-0.454389 + 0.454444i	0.642642
-0.008367 - 0.400175i	0.400262
-0.008367 + 0.400175i	0.400262
0.181582 - 0.116889i	0.215952
0.181582 + 0.116889i	0.215952
-0.125300 - 0.136356i	0.185184
-0.125300 + 0.136356i	0.185184
No root lies outside the unit circle.	
VAR satisfies the stability condition.	

Sumber: Data diolah 2023

Zou (2018) discuss the importance of characteristic root testing to ensure that the VECM model is stable before further interpretation, and they emphasize the use of stability tests in long-term dynamics testing. Based on Table 3, all modulus values below 1 indicate that all endogenous variables have met the stability requirements.

Cointegration Test

After ensuring the stationary data and the model are stable, the next step is to test the cointegration to determine if there is a long-term relationship between the variables being analyzed. The cointegration test identifies whether the variables in the system tend to move together in the long term despite short-term fluctuations. Breitung & Pesaran (2008) developed a more sensitive cointegration test method to more complex panel data, suggesting that cointegration testing should be done with caution especially on data involving multiple cross-sections.

Table 4
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.666	440.343	125.615	0.000
At most 1 *	0.530	286.760	95.754	0.000
At most 2 *	0.430	181.030	69.819	0.000
At most 3 *	0.284	102.431	47.856	0.000
At most 4 *	0.241	55.640	29.797	0.000
At most 5 *	0.114	17.030	15.495	0.029
At most 6	0.000	0.063	3.841	0.801

Trace test indicates 6 cointegrating eqn(s) at the 0.05 level

Based on Table 4, it shows that there are indications of 6 significant variables at the level of 0.05, this shows that there is a long-term relationship between the variables analyzed. After the cointegration test and model stability testing, the final step is to interpret the VECM regression results. In the VECM model, we will interpret the long-term coefficient and the short-term error correction term (ECT).

Short-term regression

The Term Error Correction Coefficient (ECT) shows how short-term imbalances will be corrected to return to long-term equilibrium. If the ECT coefficient is negative and significant, this indicates that the imbalance will be corrected in the following period. An ECT value of **-0.07045** indicates that the system is attempting to return to long-term equilibrium, as changes in higher variables in the future tend to reduce errors or imbalances. A smaller coefficient number of -0.107 indicates a slower adjustment.

Table 5 Short-Term VECM Panel Regression Results

Error Correction:	**D(LOG(ECO2))**		
	Coef	Se	T hitung
CointEq1	**-0.07045**	-0.01791	[-3.93421] ***
D (LOG (ECO2 (-1)))	-0.02561	-0.05803	[-0.44140]
D (LOG (ECO2 (-2)))	-0.50983	-0.0558	[-9.13632] ***
D (LOG (PDRB (-1)))	-0.3325	-0.17116	[-1.94256]
D (LOG (PDRB (-2)))	-0.16478	-0.16168	[-1.01920]
D (LOG (POP (-1)))	-0.44601	-0.18687	[-2.38674] **
D (LOG (POP (-2)))	-0.48605	-0.18758	[-2.59109] **
D (LOG (DAU (-1)))	0.068353	-0.01956	[3.49498] ***
D (LOG (DAU (-2)))	0.111365	-0.02458	[4.53068] ***
D (LOG (EDU (-1)))	-0.02926	-0.00808	[-3.62373] ***
D (LOG (EDU (-2)))	-0.03441	-0.0084	[-4.09476] ***
D (LOG (HEALTH (-1)))	-0.00146	-0.0071	[-0.20583]
D (LOG (HEALTH (-2)))	-0.00637	-0.0099	[-0.64364]
D (LOG (FDI (-1)))	-0.00943	-0.00535	[-1.76409] *

Error Correction:	D(LOG(ECO2))		
D (LOG (FDI (-2)))	-9.59E-05	-0.00444	[-0.02162]
C	0.116146	-0.01539	[7.54797] ***
R-squared	0.553618		
Note; * sign 10% ** sign 5% *** sign 1%			

Source: Data processed 2023

Long-term regression

The coefficient at the variable level describes the long-term relationship between variables. If there is cointegration, this coefficient indicates the impact of one variable on another variable in the long run.

Table 6 Long-Term VECM Panel Regression Results

Cointegrating Eq:	CointEq 1	Se	T hitung
LOG (ECO2 (-1))	1.000		
LOG (PDRB (-1))	0.264	-0.085	[3.11023] ***
LOG (POP (-1))	0.139	-0.081	[1.71488] *
LOG (DAU (-1))	-0.106	-0.051	[-2.09339] **
LOG (EDU (-1))	-0.077	-0.054	[-1.43301]
LOG (HEALTH (-1))	-0.078	-0.062	[-1.24158]
LOG (FDI (-1))	-0.217	-0.023	[-9.28439] ***
C	-11.534		

Source: Data processed 2023

In the short term, the GDP (Gross Regional Domestic Product) and population in 20 provinces in Indonesia have a negative influence on CO_2 emissions. The resulting increase in GDP may be driven by sectors of the economy that are less dependent on high energy consumption or that have better energy efficiency. For example, if the increase in GDP comes more from the service sector or a sector that is more focused on technology and innovation, this can reduce dependence on heavy industries that produce high CO_2 emissions. For example, the information technology, education, and financial services sectors tend to have a smaller impact on CO_2 emissions compared to industrial sectors such as manufacturing, which rely more on fossil energy and often produce higher carbon emissions (Pereira et al., 2021). However, in the long term, both GDP and population have a positive influence on CO_2 emissions. Increases in GDP are often accompanied by increased energy consumption, especially in the context of developing countries such as Indonesia, which are still dependent on natural resources and fossil energy (such as coal, oil, and gas). The higher the GDP level, the more likely it is that energy consumption will increase to support the industrial, transportation, and other economic activities sectors that have the potential to increase CO_2 emissions. This increase in energy demand is usually not offset by technological advances that are fast enough to reduce negative impacts on the environment (Sorrell, 2015).

In the short term, population increases can contribute to reductions in CO_2 emissions if those populations are distributed to smaller or isolated areas, where economic activity has not developed rapidly. This leads to relatively low energy consumption and limited CO_2 emissions. In addition, population increases accompanied by planned development efforts can increase awareness and adoption of low-carbon technologies at the household or local community level (Schäfer, et al., 2018). Meanwhile, in the long run an increase in population and GDP, there will be a faster urbanization process, where more people move to big cities. This process often increases industrial activities that rely heavily on high energy consumption, leading to increased CO_2 emissions. Large cities with higher levels of industrialization tend to produce greater emissions per capita compared to smaller or rural areas. More energy-intensive industrial sectors and larger transportation contribute significantly to CO_2 emissions (Kwilinski, et al., 2024).

As the economy develops and GDP increases, it is possible that dependence on fossil energy remains high in the long term, especially in the industrial and transportation sectors. While there is potential for a transition to renewable energy, this transition is often slow and requires significant investments, which often have not been achieved significantly in the short term. Therefore, even if GDP and population increase, greater increases in fossil energy consumption could exacerbate CO_2 emissions in the long term.

In addition, in the long run, higher economic growth can increase pressure on natural resources and increase deforestation or land conversion for infrastructure development. These activities can contribute to increased CO_2 emissions, especially in developing countries where environmental management policies are often less stringent in the early stages of economic development. Therefore, while a larger population may increase the need for green infrastructure development, the reality is that other sectors are often more focused on short-term economic expansion without considering their overall environmental impact (Schandl, et al., 2016).

In the short term, the General Allocation Fund (DAU) received by the regions has a positive influence on CO_2 emissions**.** DAU is a fiscal transfer from the central government to the regions that is used to fund various development activities, including infrastructure, education, and health. In the short term, an increase in DAU can trigger large expenditures by local governments on infrastructure development and other sectors that often require high energy consumption, such as transportation, construction, and industry. These activities can increase the demand for fossil energy and, consequently, increase CO_2 emissions in the short term. If local governments increase investment in road construction, housing, or other infrastructure projects, this could trigger an increase in the use of fossil fuels, especially in large construction projects, which results in CO_2 emissions. Fiscal transfers from central government to the regions can increase CO_2 emissions in the short term through increased energy consumption associated with infrastructure development, but greener and more sustainable policies can reduce emissions in the long term (Bletsas, et al., 2022).

At this stage, while DAU supports economic development, it also has the potential to increase higher energy consumption derived from less environmentally friendly energy sources, such as coal, oil, or gas. DAU-driven infrastructure development, especially those related to energy-intensive sectors such as transportation or the development of industrial areas, can lead to increased energy use in the short term. The increase in population and urbanization that accompanies this development will increase energy demand and lead to higher CO_2 emissions in the early stages. In addition, in the short term, local governments may not yet fully adopt renewable energy technologies or green policies that can reduce emissions. Therefore, although DAUs increase economic and development activities, they may not immediately contribute to the reduction of CO_2 emissions.

Development activities focused on the expansion of energy-intensive sectors of the economy (e.g., heavy industry and transportation) often encourage higher energy consumption. Increasing DAUs can accelerate these activities, which in turn increases CO_2 emissions, especially if the energy used does not come from renewable sources. This reflects the imbalance between economic development and environmental protection in the early stages.

However, in the long run, DAU can have a negative influence on CO_2 emissions. DAUs received by local governments can be used to develop more efficient technology in energy-intensive sectors, such as the transportation or industrial sectors. For example, increasing DAUs focused on green infrastructure (such as electric-based public transport, renewable energy, and green buildings) can reduce reliance on fossil fuels, ultimately lowering CO_2 emissions. Local governments may begin to implement more environmentally friendly policies over time, including supporting the adoption of green technologies and energy efficiency.

In the long term, greater DAU allocations for more sustainable sectors, such as renewable energy development, environmental policy, and sustainable natural resource management, can reduce dependence on fossil energy and lower emissions. DAUs used to support investments in renewable energy, energy conservation, and emission reduction policies will have a positive effect on the environment. In addition, DAU can be used to raise awareness and better planning at the regional level regarding sustainable development, which in turn can lead to more environmentally friendly policies in the long run. This includes investments in more energy-efficient technologies and greener infrastructure projects.

In the long term, with rising incomes and economic development, regions can shift their focus to more sustainable sectors or sectors that are more energy efficient, such as low-carbon services and technology sectors. This reduces reliance on industrial sectors that are more energy-intensive and produce more emissions. An increase in DAU could support this shift in economic structure, leading to a reduction in CO_2 emissions. Increased fiscal transfer funds directed towards green development or energy efficiency can lower CO_2 emissions in the long run, although initially increasing energy consumption in certain sectors (Ning, et al., 2023). Whereas Carraro, et al (2012) highlights that DAUs used for environmentally unfriendly sectors can lead to increased emissions in the short term, but the use of DAUs to fund clean technologies and emission reduction policies can reduce negative impacts on the environment in the long term.

Infrastructure development in the long term, with a focus on sustainability, will pay more attention to environmentally friendly technology. For example, the use of DAU to build smart cities that prioritize renewable-based mass transportation and buildings with high energy efficiency will help significantly lower CO_2 emissions.

Increased spending on education that places more emphasis on training or education related to sustainability and low-carbon technologies can result in a more direct impact on reducing CO2 emissions through behavioral changes in society, industry and the business sector. This creates greater awareness of the negative impacts of pollution and reduces the use of resources that cause emissions. In the long run, education alone may not be enough to drive major structural changes in energy consumption or industrial policies that affect emissions. Without firm government policies or incentives to encourage the adoption of environmentally friendly technologies, the impact of education on reducing CO2 emissions can be limited.

Spending on the health sector generally does not directly affect CO2 emissions. Health spending is more often related to improving healthcare infrastructure, vaccination, treating diseases, or improving quality of life, which is not directly related to energy consumption or emission reduction. In the long run, while improved health can contribute to economic development and a better quality of life, it will not directly reduce CO2 emissions in the absence of policies or programs that focus on sustainability or reducing emissions. Health spending is more focused on disease management and prevention, while CO2 emission reductions are more dependent on factors such as energy policy, clean technology, and natural resource management.

In the short term, despite some challenges and potential for increased emissions, FDI can have a positive influence on reducing CO2 emissions using advanced and efficient technologies that are more environmentally friendly compared to existing technologies in Indonesia. Foreign companies investing in the energy or manufacturing sectors may bring more efficient technologies in using energy, which can reduce energy consumption and CO2 emissions. These new technologies could include the use of renewable energy, fuel efficiency, or carbon emission reduction technologies in the production process. Many foreign companies prioritize sustainability in their operations. FDI entering renewable energy sectors such as solar, wind, or biomass can drive wider adoption of clean energy sources in Indonesia, which will reduce dependence on fossil fuels and lower CO2 emissions in the short term.

Variance Decomposition

Variance Decomposition is a method used to determine how much each variable contributes in explaining the fluctuations or variances of another variable in a multivariate system. Variance decomposition provides insight into how much information or shock from other variables affects changes in the target variable.

Table 7. Variance Decomposition

Variance Decomposition of LOG(ECO2):								
Period	S.E.	L(ECO2)	L(PDRB)	L(POP)	L(DAU)	L(EDU)	L(HEALTH)	L(FDI)
1	0.06	100.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.09	91.11	0.81	0.09	4.38	3.21	0.14	0.26
3	0.11	68.47	2.36	0.08	17.86	9.42	0.10	1.71
4	0.11	63.33	3.83	0.10	20.18	9.86	0.31	2.39
5	0.12	64.61	4.41	0.14	18.46	9.44	0.61	2.34
6	0.13	65.66	4.45	0.15	17.71	9.09	0.66	2.28
7	0.14	63.57	4.77	0.13	19.08	9.60	0.60	2.26
8	0.15	61.10	5.37	0.12	20.12	10.16	0.79	2.34
9	0.15	60.66	5.74	0.14	20.13	10.12	0.74	2.46
10	0.16	60.71	5.88	0.15	20.03	10.12	0.71	2.41

Source: Data processed 2023

In the 1st period CO2 Emissions contributed 100% to the variance of changes in CO2 Emissions. Then in the 5th period CO2 Emissions contributed 64.61% to the variance of changes in CO2 Emissions, DAU only contributed 18.46% to the variance of changes in DAU. EDU only accounts for 9.44% of the variance of EDU change, and GDP only accounts for 4.41% of the variance of GDP change. In the eke-10 period, CO2 emissions contributed 60.71% to the variance of changes in CO2 emissions, DAU only contributed 20.03% to the variance of changes in DAU. EDU only accounts for 10.12% of the variance of EDU changes, and GDP only accounts for 5.88% of the variance of changes in GDP Emissions.

4. CONCLUSION

In the short term, GDP (Gross Regional Domestic Product) and Population show a negative influence on CO2 emissions. This may be related to the shift of economic sectors to more energy-efficient sectors, where economic growth in the early stages can reduce emissions. However, in the long run, both GDP and Population have a positive influence on CO2 emissions. Economic and population improvements that are not balanced with proper environmental policies can increase energy consumption and CO2 emissions, leading to increased air pollution.

In the short term, the Central to Regional Transfer Fund (DAU) has a positive influence on CO2 emissions. Increased allocation of regional funds may encourage economic activity in regions that use more fossil energy, leading to an increase in CO2 emissions soon. However, in the long run, DAU has a negative effect on CO2 emissions. This may be because local governments invest transfer funds in sectors that support sustainability and energy efficiency, thereby reducing CO2 emissions over time.

Education spending in the short term has a negative influence on CO2 emissions, likely due to increased awareness and more efficient adoption of environmentally friendly technologies. However, in the long term, these expenditures do not have a significant effect on CO2 emissions, as the expected behavioral change has not been fully achieved.

Health expenditure has no significant influence on CO2 emissions, either in the short or long term, suggesting that the health sector is indirectly linked to the reduction or increase of CO2 emissions.

FDI in both the short and long term has a negative influence on CO2 emissions. This may reflect that foreign investment is often directed at more energy-efficient sectors or focuses on clean technologies that reduce CO2 emissions.

To reduce the long-term negative impact of GDP and population growth on CO2 emissions, it is recommended that government policies encourage the adoption of renewable energy and energy efficiency, especially in rapidly developing sectors. Local governments should focus on investing in green infrastructure and technology that reduces emissions in the long term.

The allocation of Central to Regional Transfer Funds (DAU) should be directed to support projects that focus on sustainability and energy efficiency. Although DAUs have a positive effect on CO2 emissions in the short term, with the right allocation, these funds can be used to reduce CO2 emissions through increased environmental awareness and investment in green technologies at the regional level.

FDI focused on investment in greener sectors and clean technology needs to be encouraged. Strengthening policies that attract foreign investors in the field of renewable energy and the low-carbon sector can accelerate Indonesia's energy transition and reduce CO2 emissions.

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