Socio-economic and Environmental Degradation: The Causal Relationship Analysis to Achieve SDGs in Indonesia

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Abstract. Sustainable development is becoming a new development direction for countries in the world because of the agreement of the Sustainable Development Goals (SDGs). Therefore, development policies in Indonesia must consider the linkages between economic growth and the environment. This study aims to analyze the causal relationship between economic growth, CO_2 emissions, urbanization, energy consumption, and trade openness in Indonesia. Annual data for the period 1980-2019 were analyzed using Granger causality test and Vector Error Correction Model to answer the research objectives. The Granger causality test shows energy consumption is related in one direction to CO_2 emissions, and also urbanization to CO_2 emissions, energy consumption, and trade openness. In the short term, there is no significant variable that affects the level of CO_2 emissions, but in the long term, energy consumption, economic growth, trade openness, and urbanization have an impact on CO_2 emissions in Indonesia. Shocks of economic growth, energy consumption, trade openness, and urbanization have an impact on the increase of CO_2 emissions. Moreover, the contribution of the variables of energy consumption, economic growth, trade openness, and urbanization to CO_2 emissions tends to increase.

Keyword: Development policies, Economic growth, Environment, Sustainable development

1. Introduction

The Sustainable Development Goals (SDGs) become global development agenda that consist of three dimensions (economic, social, and environmental) and are often described as an effort to improve life quality adapted to the carrying capacity of the environment [1,2]. Therefore, the government must pay attention to complementary relationships or trade-offs among the dimensions to ensure that human actions and behaviours follow the sustainable paradigm [3]. However, this sustainable development is a challenge for most developing countries such as Indonesia because they need to continuously improve their economy without compromising environmental sustainability [4].

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The economic growth linkages with environmental conditions have been widely studied before. In nine European countries, economic growth, CO_2 emissions, and fossil fuel consumption have a unidirectional or bidirectional causal relationship [5]. This relationship also occurs in West African region [6]. Research Jian et al [7] in China reports that energy consumption and financial development have a unidirectional relationship [7]. These variables also contribute to the increase in CO_2 emissions.

Indonesia needs to consider the relations of socio-economic variables and environmental conditions when formulating its development policies. However, previous research has led to conclusions that are still debatable. According to Hwang and Yoo [8], Vo, Vo, and Le [9], and Munir, Lean, and Smyth [10], economic growth in Indonesia is strongly linked to CO_2 emissions and energy consumption. However, Azam et al [11] and Nuryartono and Rifai [12] reported that Indonesia's economic growth is not related to CO_2 emission. Therefore, research about economic growth relations to environmental conditions is still needed to strengthen the empirical facts of the relationship between these two aspects together with the variables of trade openness and urbanization to obtain more comprehensive empirical facts for reporting Indonesia's development

2. Methods

This study used secondary data compiled from various sources. The data used are Indonesian time series data with an annual period of 1980-2019. The data consist of CO_2 emissions (tons/capita), GDP/capita base year 2015 (USD), trade openness (percentage of exports and imports to total GDP), urbanization (percentage of urban population to total population), and primary energy consumption (gigajoules per capita).

The collected data were quantitatively analyzed using Granger causality and Vector Error Correction Model (VECM). The type of causal relationship between variables (unidirectional or bidirectional) analyzed by the Granger causality test. While VECM is used to measure how strong the influence between all variables. VECM is applied because the variables are not stationary but have the potential to be cointegrated [13]. The VECM application follows the following steps, namely unit root test, optimal lag test, VAR stability test, cointegration test, impulse response function (IRF), and forecast error variance decomposition (FEVD) [13]. When the variables are cointegrated, the VECM equation is [7,14]:

$$\Delta LNENEt = \varphi 1 + \sum_{i=1}^{n} a1i\Delta LNENE t-i + \sum_{j=1}^{n} \beta 1i\Delta LNEMI t-j + \sum_{k=1}^{n} ɣ1i\Delta LNGDP t-k + \sum_{P=1}^{n} \delta 1i\Delta TRD t-P + \sum_{q=1}^{n} \Theta 1i\Delta URB t-q + Ɛ1 ECTt\text{-}1 + \mu 1 \quad (1)$$

$$\Delta LNEMIt = \varphi 2 + \sum_{i=1}^{n} a2i\Delta LNEMI t-i + \sum_{j=1}^{n} \beta 2j\Delta LNENE t-j + \sum_{k=1}^{n} ɣ2k\Delta LNGDP t-k + \sum_{P=1}^{n} \delta 2p\Delta TRD t-P + \sum_{q=1}^{n} \Theta 2q\Delta URB t-q + Ɛ2\ ECTt\text{-}1 + \mu 2t \quad (2)$$

$$\Delta LNGDPt = \varphi 3 + \sum_{i=1}^{n} a3i\Delta LNGDP t-i + \sum_{j=1}^{n} \beta 3j\Delta LNENE t-j + \sum_{k=1}^{n} ɣ3k\Delta LNEMI t-k + \sum_{P=1}^{n} \delta 3p\Delta TRD t-P + \sum_{q=1}^{n} \Theta 3q\Delta URB t-q + Ɛ3\ ECTt\text{-}1 + \mu 3t \quad (3)$$

$$\Delta TRDt = \varphi 4 + \sum_{i=1}^{n} a4i\Delta TRD t-i + \sum_{j=1}^{n} \beta 4j\Delta LNENE t-j + \sum_{k=1}^{n} ɣ4k\Delta LNEMI t-k + \sum_{P=1}^{n} \delta 4p\Delta LNGDP t-P + \sum_{q=1}^{n} \Theta 4q\Delta URB t-q + Ɛ4\ ECTt\text{-}1 + \mu 4t \quad (4)$$

$$\Delta URBt = \varphi 5 + \sum_{i=1}^{n} a5i\Delta URB t-i + \sum_{j=1}^{n} \beta 5j\Delta LNENE t-j + \sum_{k=1}^{n} ɣ5k\Delta LNEMI t-k + \sum_{P=1}^{n} \delta 5p\Delta LNGDP t-P + \sum_{q=1}^{n} \Theta 5q\Delta TRD t-q + Ɛ5\ ECTt\text{-}1 + \mu 5t \quad (5)$$

Where, EMI is CO_2 emissions; ENE is primary energy consumption; GDP is GDP/capita base year 2015; TRD is trade openness; URB is urbanization; φ, α, β, γ, δ, and ϴ are the polynomial coefficients; n is the lag; ECTt-1 is the correction term.

3. Results and Discussion

3.1 Unit Root Test

Augmented Dickey-Fuller (ADF) was used for the unit root test. A variable is considered stationary or has no unit root if the ADF statistic value is less than the MacKinnon critical value [4,13]. The unit root test show that all variables are not stationary at the level (1% level of significance). This indicate that the data used meet the requirements for estimation with VECM, as there is at least one variable that is not stationary at the level. Next, the test was performed for the first difference, and produces only the urbanization variable was not stationary. All the variables used were stationary in second difference.

3.2 Optimum Lag Determination

In addition, the determination of optimal lag in the model is used. Based on the criteria LR, the final prediction error (FPE), and the Akaike information criterion (AIC), the optimal lag chosen in this study was lag 3. The formed VAR system of equations must be tested for stability by the VAR stability test by calculating the roots of the polynomial function [13]. VAR is considered stable if all roots have a modulus < 1 [15], and the VAR system in this study has fulfilled this because the modulus of the VAR system in this study ranged from 0.119031-0.971337.

3.3 Cointegration Test

The variables used are not stationary on the level, have implications for the Johansen cointegration test used with two methods, namely Trace and Max-Eigen [7]. H_0, which states that there is no integration, is rejected because the probability value for both Trace and Max-Eigen is less than the 5% significance level. Therefore, it's concluded that there is cointegration relationship between the variables used.

3.4 Granger Causality

Information on the relationship between variables is useful for formulating the right energy policy for sustainable economic growth [7]. According to Granger causality test, energy consumption affects CO_2 emissions and vice versa that CO_2 emissions do not affect energy consumption. This means, that the relationship between these two variables is a unidirectional causality. These results are consistent with studies [9,12] focusing on the Indonesian state, which reported that energy consumption is related to CO_2 emissions, but not vice versa. Other studies that find a unidirectional causal relationship between this two variables include Hossain [16] in Japan and Xue et al. [5] in the Netherlands.

Table 1. Granger causality test results

Null hypothesis	F-statistic	Prob.	Null hypothesis	F-statistic	Prob.
ENE-EMI	3.33084	0.0326*	TRD-ENE	0.19831	0.8967
EMI-ENE	0.34903	0.7901	ENE-TRD	0.92979	0.4384
GDP-EMI	1.29079	0.2956	URB-ENE	2.80869	0.0564**
EMI-GDP	0.09326	0.9632	ENE-URB	0.88736	0.4589
TRD-EMI	0.76307	0.5237	TRD-GDP	0.10234	0.9580
EMI-TRD	1.08924	0.3687	GDP-TRD	0.46359	0.7098
URB-EMI	5.13547	0.0055*	URB-GDP	1.02619	0.3950
EMI-URB	1.03031	0.3932	GDP-URB	1.97839	0.1384
GDP-ENE	0.72974	0.5423	URB-TRD	2.66004	0.0661**
ENE-GDP	0.42999	0.7330	TRD-URB	13.6672	8.E-06

Notes: * significant at 5% level; ** significant at 10% level

Table 1 shows that urbanization is a variable that has unidirectional causality with other variables such as CO_2 emissions, energy consumption, and trade openness. This can be happened because the higher rate of urbanization increases the transportation process, which requires more energy consumption and causes greater CO_2 emissions. Urbanization causes the population in cities to grow faster than in other areas as workers migrate from rural areas to cities for a better life and education. Population pressure on resources in urban areas leads to environmental pollution [16]. Urban population is also considered as a source of pollution that pollutes the environment [17].

Urbanization may increase CO_2 emissions by increasing energy consumption and opening trade. This can be seen from the unidirectional causality between urbanization and energy consumption and trade openness. Urbanization affects energy consumption and trade openness, but not the other way around. Urbanization increases consumption goods along with the increase in the number of urban residents. These consumption goods can be met by domestic production or by imports from other countries through international trade activities. More consumption and further processing of goods due to greater trade openness impacts leads to increased CO_2 emissions [16].

3.5 VECM Results

In the short term, there are no significant variables affecting the level of CO_2 emissions in Indonesia, neither lag-1, lag-2, nor lag-3. This estimation is consistent with studies [8,12] that energy consumption and economic growth do not significantly affect CO_2 emissions in Indonesia. However, Bashir et al [4] state that Indonesia's energy consumption and economic growth affect CO_2 emissions in the short term.

Table 2. VECM estimate results

Variable	Coefficient	t-statistic	Variable	Coefficient	t-statistic
Long-Term			Short-Term		
Ln_ENE(-1)	-11.05508	[-6.51376]	CointEq1	-0.002072	[-0.07490]
Ln_GDP(-1)	2.426488	[2.05704]	D(EMI(-1))	-0.491444	[-1.68438]
TRD(-1)	0.087290	[7.27488]	D(EMI(-2))	-0.500356	[-1.65967]
URB(-1)	0.329545	[3.27410]	D(EMI(-3))	0.050565	[0.18730]

D(ENE(-1))	0.579918	[1.64799]
D(ENE(-2))	0.165602	[0.43936]
D(ENE(-3))	-0.483293	[-1.43738]
D(GDP(-1))	0.304932	[0.65480]
D(GDP(-2))	-0.061234	[-0.12764]
D(GDP(-3))	0.662398	[1.41017]
D(TRD(-1))	0.001769	[0.78823]
D(TRD(-2))	-0.000707	[-0.40287]
D(TRD(-3))	0.000518	[0.29090]
D(URB(-1))	0.050178	[0.26130]
D(URB(-2))	-0.095775	[-0.41723]
D(URB(-3))	0.174399	[1.43307]

Notes: Figures in bold indicate significant at the 10% level of significance

In the long term, all variables have a significant influence on the CO_2 emissions level in Indonesia. Energy consumption variable has a coefficient value of 11.05 with a negative sign, which means that increasing energy consumption by 1% will reduce the level of CO_2 emissions by 11.05% in the long term, ceteris paribus. This can happen by changing the consumption of environmentally friendly energy so that CO_2 emissions can be reduced. Economic growth with a coefficient of 2.42 means that increasing economic growth by 1% will increase CO_2 emissions by 2.42%, ceteris paribus. This result is in accordance with the study of [8,14], which found that economic growth as a proxy for GDP per capita has a positive influence on CO_2 emissions.

The variables trade openness and urbanization also have a positive impact on long-term CO_2 emissions with coefficients of 0.08 and 0.32, respectively. This coefficient implies that increasing trade openness by 1% will increase CO_2 emissions by 0.08%, ceteris paribus. The results of this study are consistent with Kasman and Duman [17], who concluded that trade openness increases CO_2 emissions. This condition may occur because the increase in trade volume causes an increase in pollution from production activities and distribution of export goods. The urbanization coefficient of 0.32 means that increasing urbanization by 1% will increase CO_2 emissions by 0.32%, ceteris paribus.

3.6 Impulse Response Function (IRF)

Impulse Response Function (IRF) was performed up to 20th period and show that energy consumption shocks influence CO_2 emissions. CO_2 emissions responded positively to energy consumption shocks until the 4th period when they decreased significantly with a value of 0.005644, and then increased again until the 20th period with a value of 0.035910. This result is in line with other studies reporting that shocks in energy consumption impact CO_2 emissions in China and India [7,18].

The economic growth shocks have positive influence on increasing CO_2 emissions until the 5th period and then fluctuates. The maximum response occurred in the 10th period with a value of 0.031606 and then showed a downward trend until the 20th period. Consistent with the results of this study, Ohlan [18] reported that CO_2 emissions in India responded to shocks in economic growth until the 22nd period. Jian et al [7] also reported that economic growth shocks had a positive influence on China's CO_2 emissions only until the second period and a negative effect thereafter, or that economic growth succeeded in preventing CO_2 emissions in the long term.

Trade openness shocks have a positive effect on CO_2 emissions. The decrease occurred only in the 2nd period with a value of 0.002683 and then increased until the 20th period with a value of 0.024770. The urbanization shock also has a positive effect on CO_2 emissions. The response of CO_2 emissions to urbanization shocks tends to increase up to the 20th period. Consistent with these results, Ohlan [18] reports that CO_2 emissions in India respond positively to population density shocks throughout the analysis period. The phenomenon of high urbanization is predicted to affect increasing energy demand while leading to environmental degradation [19]. Overall, the shocks of all variables responded positively to CO_2 emissions, and these results confirm the VECM results discussed earlier.

3.7 Forecast Error Variance Decomposition (FEVD)

FEVD analysis was performed to compare the percentage contribution of all variables to changes in CO_2 emissions [7,18]. The FEVD indicates the proportion of the dependent variable's movement that is due to the shock of the variable itself and other variables. The results show that CO_2 emissions itself contribute to changes in CO_2 emissions with a decreasing trend. In contrast, the contribution of other variables tends to increase.

Besides the CO_2 emissions contribution, energy consumption has the largest effect on CO_2 emissions with a value of 30.30% in the 20th period. The impact of economic growth also shows an increasing trend with a contribution of 23.84% in the 20th period. The contribution of trade openness to the changes in CO_2 emissions is also relatively large, with a contribution of 23.84% in the 20th period, while the contribution of urbanization is relatively small. Several previous studies have also confirmed that the CO_2 emissions contribution to changes in CO_2 emissions itself tends to decrease, while the contribution of other variables tends to increase, as reported by Jian et al [7] for China and Ohlan [18] for India. This result confirms the importance of a low-carbon economy in Indonesia. Therefore, renewable energy production and consumption are more prominent than measures to reduce CO_2 emissions [7,18]. The results of the FEVD analysis also confirm the VECM results, namely energy consumption as the variable with the largest coefficient compared to the others.

4. Conclusion

It can be concluded that energy consumption in Indonesia has a causal relationship with CO_2 emissions. While urbanization affects emissions, energy consumption, and trade openness, so the level of urbanization should be the government's concern when planning sustainable development. In addition, the VECM estimation results show that there are no variables that affect the level of CO_2 emissions in the short term, but in the long term, energy consumption, economic growth, trade openness, and urbanization have a significant effect on CO_2 emissions level in Indonesia. Further analysis shows that shocks in the variables of economic growth, energy consumption, trade openness, and urbanization have an impact on the increase in CO_2 emissions. However, from the FEVD results, CO_2 emissions contribute to changes in CO_2 emissions with a decreasing trend, while the contribution of energy consumption, economic growth, trade openness, and urbanization tends to increase.

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