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Analyzing Sustainable Development in Indonesia Based on Environmental Kuznet Curve

Wella Amalia Yanuarti[1], Lucky Rachmawati[2]✉

[1,2]Universitas Negeri Surabaya, East Java, Indonesia

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Abstract

Sustainable development is long term development with economic, social, and environmental aspects. Development in Indonesia is a trade off in which an increase in income will increase degradasi environemntal. This research use the EKC theory that connects aspects of economic growth to the environment represented by CO2. The VECM analysis technique is used to see the cointegration of short and long term relationships. In the short term it show that GDP, GDP2 has significant effect on CO2, while HDI has no effect. The results of this studi show that EKC curve is rejected in a U-shape so that sustainable development is weak. In the long term GDP, GDP2, and HDI have significat effect on CO2. The result of the show support for the EKC theory with an inverted U-shaped curve in the long run so that sustainable development is strong. It show that Indonesia is a country whose economic growth depends on energy consumption. This study provides an overview of government policies to reduce carbon dioxide gas with a tax holidays for FDI to encourage green industries, encourage renewable energy sources. Within the scope of education provides an environment-based learning curriculum.

Key words : CO2, GDP, HDI, EKC, Sustainable Development

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✉ Corresponding author : Lucky Rachmawati
Address: Universitas Negeri Surabaya, East Java, Indonesia
E-mail: luckyrachmawati@unesa.ac.id

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INTRODUCTION

Sustainable development is a development theory that aims to determine present needs without compromising future needs by linking economic, social and environmental aspects (Nuansa & Widodo, 2018). The importance of measuring sustainable development concerns moral reasons, related to ecology that does not threaten biological functions, as well as economic sustainability (Perman et al., 2003). The economic aspect is represented by GDP per capita as a conventional measure, the social aspect is represented by the human development index as the subject of human resources, while the environmental aspect in this study uses carbon emissions and between aspects is balanced with government policies to achieve sustainable development.

Abdoellah (2016) the concept of sustainable development is an old perspective in The Brundland Report 1987 which was discussed at the United Nations and then poured into the main points of the SDGs, but the commitment and awareness of countries in the world in implementing the pillars of sustainable development was only agreed in 2015.

Measurement of the success of the development of developing countries is shown by the indicator of economic growth (GDP per capita) as a measure used by the World Bank in classifying the level of development of countries (Nuansa & Widodo, 2018). In fact, GDP per capita is not very suitable to be used as a benchmark for the success of development because it is unable to measure aspects of life from the aspect of happiness and people's welfare. (Arsyad, 2015; Drabsch, 2012). the weakness of gdp per capita is that it ignores differences in characteristics between countries and does not take into account the depletion and degradation of natural resources and the environment so that economic growth is paid for by damage (Fauzi & Oktavianus, 2015). Measurement of development with the concept of sustainable is more recommended as a form of concern for the environment in accordance with the theory (Nordhaus & James, 1973).

Malthus' theory states that the rapid rate of population growth causes a higher demand for needs that is faster than the growth of natural resources to meet needs (Cahyono, 2020). Increasing environmental damage can increase economic development, this is in accordance with the situation where the initial development of the primary sector depended on agriculture which produced little waste, then expanded to the industrial and manufacturing sectors which increased pollution and environmental damage (Gyamfi et al., 2021). The many problems faced by the world require measurement of sustainable development research that considers the environment into the scope of economic development (Leal Filho et al., 2018). Bali Swain & Yang-Wallentin (2020) the size of social and environmental pillars is the most effective factor for developed countries, while the economic and social pillars are effective pillars for sustainable development in developing countries. Sustainable economic development is realized in two situations (1) weak sustainability shows that human resources can reduce natural resources; (2) strong sustainability, indicating that human resources and natural resources complement each other and cannot be exchanged (Bashir et al., 2019).

Indonesia's economic growth is relatively stable with a dynamic GDP growth value shown during 1996-2020 (Table 1). Economic growth includes the proportion and contribution of sectors to GDP, the agricultural, industrial, manufacturing and service sectors. During the 1994-2014, Indonesia's average economic growth was stable at around 4.83% (Nugraha & Osman, 2019). Service and industrial sectors is a leading sector that contributes the most to economic income, showing that Indonesia is no longer dependent on natural resources. Economic growth in Indonesia has increased but has not been able to improve people's welfare which is not balanced with equity as evidenced by the existence of economic inequality and poverty depth (Abdoellah, 2016).

Based on table 1, population growth in Indonesia averaged 18,406 in the period 1996-2020. Indonesia is a country with the largest population in Southeast Asia and the 4th largest in the world with an average population growth of 1.38% per year during 2014 (Nugraha & Osman, 2019). Based on the human capital index, Indonesia is in the range of 60-70, in the medium category compared to Malaysia and Singapore which are already in the high category (Fauzi & Oxtavianus, 2014).

Table 1. The Ratio of Economic, Social, and Environmental in Indonesia Period 1996-2020

Indicators	1996	2002	2008	2014	2020
Population total[(a)]	199.901	217.357	235.469	255.128	273.523
GDP[(b)]	532.568	1.821.833	4.948.688	10.569.705	15.438.017
The add value services[(b)]	212.345	730.642	1.853.655	4.464.874	6.853.849
The add value manufacturing[(b)]	136.426	582.135	1.376.441	2.227.584	3.068.041
The add value industry[(b)]	231.431	86.984	2.378.376	4.431.702	5.905.289
The add value agriculture[(b)]	88.791	297.317	716.656	1.409.655	2.115.389
CO_2 emissions[(c)]	255.067	310.818	366.293	498.973	589.500

Source: World Development Indicators (2022) and Our World in Data (2022) (a) in millions people (b) in billions current (c) in millions of Co_2

The environmental aspect shows that environmental damage occurs more and more every year with the increase in the Gini coefficient and natural disasters which show that around 2013 there have been more than 1,700 floods in a year (Fauzi & Oxtavianus, 2014). Based on the 2020 Environmental Performance Index, Indonesia's environmental quality is ranked 133, very far from Singapore, which is ranked 49 (Huang & Xu, 2014). Based on table 1, the average increase in carbon gas in Indonesia is in line with the increase in GDP, which is evidence that development in Indonesia is not environmenttally friendly. Data collected by the Postdam Institute for Climate Impact Research during Indonesia's greenhouse gas emissions reached 2.4 billion tons in 2015 (Warren et al., 2017). Indonesia is one of the three countries with the lowest Co_2 emission reduction rate among G20 countries during 2013-2018 (Purjayanto, 2022).

The Environmental Kuznets Curve hypothesis stems from Simon Kuznets theory in 1950. This theory describes economic growth as a long-term increase in a country and its ability to meet the needs of its people in accordance with advanced technology and modern institutions. The Kuznet Curve links economic growth with income inequality in an inverted U shape. Arsyad (2015, p. 292) at the beginning of development levels of income and inequality are high, but after reaching an inflection point, increased income can reduce inequality.

Grossman & Krueger (1991); Panayotou (1993) Incorporating environmental scope into economic development is known as the environmental kuznet curve hypothesis, namely the economic impact on the environment increases in the early stages and then decreases at a certain level of income due to technological developents with an inverted U-shaped curve. This EKC hypothesis describes the scope of development in Indonesia which is development oriented which is growth oriented and has an impact on the environment as return. (Fauzi & Oxtavianus, 2014). Callan & Thomas (2013) explain the increasing environmental damage in line with per capita income in the early stages, especially in developing countries which are marked by the process of industrialization. The government's efforts to reduce the impact of negative externalities on the environment according to UU No. 32 with environment-based development and contains components for the implementation of sustainable development at the national and regional levels (Suparmoko, 2020)

The research result of (Beckerman, 1992) shows that the GDP growth rate will improve environmental quality. The EKC is proven to be appropriate in rich countries and not proven in developing countries in Asia (Nikensari et al., 2019). The regional research in Indonesia show that in Java Island economic development, quality of human resources, and population density on environmental damage show that an increase in regional GDP can reduce environmental damage, but there is potential for environmental damage related to economic development. HDI has the potential to reduce environmental quality (Purjayanto, 2022).

The changes in environmental quality have become an issue in development factors in a developing country, especially Indonesia, which is more concerned with economic growth. Economic development in Indonesia is traditional and short term. This is an obstacle in achieving Indonesia's target of advancing 2030 with a projected sustainable development. Long-term development analysis through the EKC hypothesis is a hot topic to be discussed (Xu et al., 2021). The outcome of (Gyamfi et al., 2021) supports the long-term inverted U-EKC curve in seven countries, including Indonesia using the PMG-ARDL method for the 1995-2018 period. The results of the study explain that increasing the use of renewable energy can reduce pollution. Sugiawan & Managi,(2016) shows that the research results support the EKC curve using the ARDL method for the 1971-2010 period, but the relationship between variables is not significant. Setiawan et al. (2022) shows the results of research that support the EKC VECM model for the 1974-2020 period with the variables GDP, population, electricity consumption, consumption of fossil energy, international trade and the Kyoto Protocol.

The EKC curve is not proven in Indonesia in research (Nikensari et al., 2019) because developing countries are still in the early process of development CO_2 rises when GDP is still low besides that the factor of population increase is greater than the increase in carbon gas populartion resulting in the EKC hypothesis not being proven. Saboori (2012) reject the EKC curve using the ARDL method for the period 1971-2007 with the variables of commercial energy consumption and world trade ratio. Jafari et al. (2012) shows that there is no correlation between GDP and CO_2 emissions for the period 1971-2007 using the Toda-Yamamoto procedure. This study rejects the EKC curve with an increase in urban population can increase gas emissions. Sasana & Aminata (2019) shows the result of study also rejected hypothesis EKC in Indonesia.

This study uses the VECM model to analyze sustainable development using the inverted-U EKC theory. The VECM model in this study is to see cointegration between variables in the short and long term. Sarkodie & Strezov (2019); Sun et al. (2022) concluded that the EKC curve can also be U-shaped in some studies. The majority of studies use CO_2 emissions and GDP per capita, but the explanatory variables used are different (Nuansa & Widodo, 2018). So, it can be have a differences in research results.

We investigated the EKC hypothesis in Indonesia using the VECM technique showing the differences in the EKC hypothesis long term with short term which was not applied in previous research. (Setiawan & Anwar, 2022) did not conclude about turning points and the formation of curves in the short term. We offer a new perspective on types sustainable development and forecasting to project the model forward in this study based on empirical evidence.

The hypothesis in this study can be formulated Ha1: there is an effect in the short term of sustainable development according to the theory of Environmental Kuznet Curve; Ha2: there is an influence in the long term of sustainable development in accordance with the theory of the Environmental Kuznet Curve.

METHOD

This study uses time series data for the period 1990-2020 with CO_2 in million tonnes sourced from (Our World in Data, 2021), GDP per capita current LCU in million rupiah sourced from (World Development Indicators, 2021), and HDI in percent sourced from (UNDP, 2021). This study uses VECM analysis to look at long-term and short-term cointegration relationships. The correlation between CO_2 emissions, GDP per capita, and HDI can be written in the regression model as follows:

$$LogCO2 = f(LogGDP, LogGDP2, LogHDI) \quad (1)$$

Where CO2 = carbon emission, GDP = GDP per capita, GDP2 = GDP to show quadratic directions EKC, HDI = IPM. We transform all variables in logarithmic form to overcome the problem of heteroscedasticity and induce stationarity in the variance-covariance matrix and in addition to the constants in all series (Ahmad et al., 2016).

Estimation in the VECM technique has 4 steps (Chen & Taylor, 2019; Nugraha & Osman, 2019). The first stage of the stationarity test is used to ensure that all data is integrated to the same degree. If the data is not stationary, the estimated results indicate a problem of false and sensitive regression which affects the results of the causality test (Ali et al., 2015). Data estimation uses VAR (Vector Autoregressive) if the data is stationary at the level and using VECM if stationary at the 1st difference (Setiawan & Anwar, 2022). Test the stationarity of the data using the ADF as proposed (Dickey & Fuller, 1981) and PP unit root test as recommended (Phillips & Perron, 1988). Nugraha & Osman (2019) combined ADF and PP tests to make the integration sequences for all series robust.

The second step determines the cointegration test to see the long-term relationship between variables. Cointegration test are predetermined by the lag length of the underlying VAR. This test is used to choose the right lag length to test the dynamic relationship between variablesl (Ali et al., 2015). The lag length test in this study was determined based on the highest number of stars based on Final Prediction Error, Akaike Information Criterion, Schawarz Information Criterion, and Hannan Quinnon (Sun et al., 2022). After the lag length test is determined, then the cointegration test is carried out by comparing the Max Eigen Test and Trace Statistics Test (Setiawan & Anwar, 2022).

The third step determines the VECM model to construct the model. The level of significance of short-term and long-term relationships with a degree of confidence of 5% with the value of t-statistics > t-table or comparing the probability t < 0.05. Engle & Granger (1987) states that once a variable is determined to cointegrate, there is always a corresponding error correction term, then the change in the dependent variable is a function of the degree of imba-lance in the cointegration relationship as captured by the ECT. This functional form can be written in the following model the short-run interactions below:

$$LogCO2_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\, logCO2_{t-i} + \sum_{i=1}^{q} \beta_{2i} logGDP_{t-i} + \sum_{i=1}^{r} \beta_{3i} logGDP2_{t-i} + \sum_{i=1}^{s} \beta_{4i} loghdi_{t-i} + \varepsilon_t \quad (2)$$

This functional form can be written in the following model the long-run interactions below:

$$LogCO2_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\, logCO2_{t-i} + \sum_{i=1}^{q} \beta_{2i} logGDP_{t-i} + \sum_{i=1}^{r} \beta_{3i} logGDP2_{t-i} + \sum_{i=1}^{s} \beta_{4i} loghdi_{t-i} + \pi ECT_{t-1} + \varepsilon_t \quad (3)$$

Where β_0 = kontanta, 1,2,3,4 = koefisien, ε_t= error correction term, π = speed adjustment parameter, ECT_{t-1}= error correction term with lag. ECT as a representation of the error correction period in stabilizing the imbalance in the model.

The final stage is a diagnostic test so that the data is free from heteroscedasticity and autocorrelation (Chen & Taylor, 2019). This is done so that the model built is feasible and can be interpreted. The heteroscedasticity test in this study used the Breush Pagan Godfrey test while the autocorrelation test could use the LM test (Wahyudi, 2016, p. 168). Data is free from heteroscedasticity and autocorrelation if the probability value > 5% significance level.

The EKC model test is seen by the characteristics of the curve represented by the coefficients 1,2,3 or $\alpha_1, \alpha_2, \alpha_3$ (Sun et al., 2022). The shape of the EKC curve and its analysis is shown in below:

Table 2. The Shape of EKC Curve and Analysis

Model	Parameter Values	CO2 and GDP Relationship	Curve Shape
1	$\alpha_1 = 0, \alpha_2 = 0, \alpha_3 = 0$	No correlation	None
2	$\alpha_1 < 0, \alpha_2 = 0, \alpha_3 = 0$	As GDP enhances, carbon emissions increase	Linearly monotonically decreasing
3	$\alpha_1 > 0, \alpha_2 = 0, \alpha_3 = 0$	As GDP enhances, carbon emissions decrease	linearly monotonically increasing
4	$\alpha_1 > 0, \alpha_2 < 0, \alpha_3 = 0$	As GDP enhances, carbon emissions first increase and then decrease	Inverted-U
5	$\alpha_1 < 0, \alpha_2 > 0, \alpha_3 = 0$	As GDP enhances, carbon emissions first decrease and then increase	U-Shape
6	$\alpha_1 > 0, \alpha_2 < 0, \alpha_3 > 0$	As GDP enhances, carbon emissions first increase then decrease, and then rise again	N-Shape
7	$\alpha_1 < 0, \alpha_2 > 0, \alpha_3 < 0$	As GDP increases, carbon emissions first decrease, then increase, and them fall again.	Inverted N-Shape

Source: Sun et al. (2022)

RESULTS AND DISCUSSION

The unit root test using ADF and PP shows that is not stationary at the level. Then the data must be stationary on the 1st difference to the same degree for all data variables. The unit root 1st difference results show stationary data with a probability value of < 0.05 at a significance level of 5%. These results confirm that this research can be continued for the next step, namely the cointegration test to see the relationship between variables in the long term. The results of the unit root test are shown in table 3 below.

Table 3. The Result Unit Root Test

	Level			**1st difference**		
Method	Statistic	Prob.**	Obs	Statistic	Prob.**	Obs
ADF - Fisher Chi-square	3.11439	0.7944	89	28.9421	0.0001	86
PP - Fisher Chi-square	3.94300	0.6844	90	43.3641	0.0000	87

Note: If the probability < 0.05, then Ho is accepted, the variabel have stationary.

Determine the optimum lag length in the model using the lag length criterion test. The results of the lag length test in this study shows lag 1 with the most stars based on FPE, AIC, SC, and HQ criteria shown in table 4 below.

Table 4. The Result Lag Length Criteria Test

Lag	LR	FPE	AIC	SC	HQ
0	NA	5.34e+29	76.96388	77.10662	77.00752
1	222.4688*	9.63e+25*	68.33720*	68.90815*	68.51175*
2	9.156333	1.22e+26	68.54404	69.54320	68.84949
3	3.669753	2.02e+26	68.98302	70.41039	69.41938

Note: Lag order selected by the criterions.

The next stage is the cointegration test to see the model in the long-term relationship between variables. The outcome of the cointegration johansen test in this study are based Max Eigenvalue and Trace Statistics > 5% critical value. Cointegration results show that the model has a long-term relationship in the following table:

Table 5. The Result Johansen Cointegration Test

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.531384	41.33763	29.79707	0.0015
At most 1 *	0.444112	20.11441	15.49471	0.0093
At most 2	0.122942	3.673114	3.841466	0.0553

Note: indicates the degree of significance of the p-value at the 5% level.

The VECM test in this research model can be used which is based on the 1st difference in the stationarity test and there is a cointegration relationship. The VECM model is determined based on the value of t-statistics > t-table at a significance level of 5% in table 6.

Table 6. The Result VECM Test

Variable	Coefficient	T-Statistic
Short Term		
C	0.050590	
LOG(GDP(-1))	-9.910742	-2.77835
LOG(GDP(-1))^2	0.315464	2.80724
LOG(HDI(-1))	-1.850587	-0.57822
Long Term		
C	-20.37718	
LOG(GDP(-1))	1.925637	4.44582
LOG(GDP(-1))^2	-0.055713	-4.86983
LOG(HDI(-1))	-3.816086	-2.58696
R-squared	0.339010	
Adj. R-squared	0.195317	
F-statistic	2.359263	

Note: Significant 5%, t-statistic < t-table then Ho is rejecte

Table 7. The Result Autokorelasi LM and Heteroskedastisitas Chi-Square Test

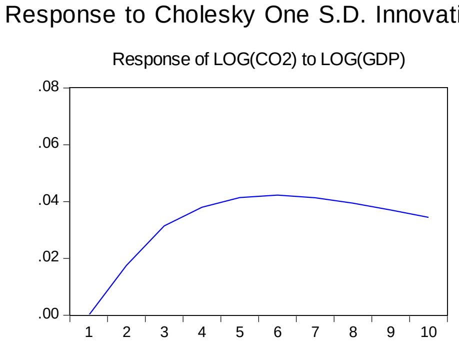
Probabilitas LM-Statistics	Breush Pagan Godfrey Probabilitas Chi-Square
0.6536	0.1522

Note: Probabilitas > 0.05 then Ho is accepted

Based on the results of the VECM model test table 5 the estimation results show an R-squred value of 33.9% while the remaining 66.1% is explained by other variables outside the model. In the EKC study, the variable that had the greatest influence but was not included in the model was the population level. This result prove the study (Zhu & Peng, 2012), that changes in energy use and population are the main drivers of carbon emission intensity. One of the variables that affect carbon emissions is energy consumption and economic growth (Ali et al., 2015; Pao & Tsai at Nikensari et al., 2019; Nugraha & Osman, 2019).

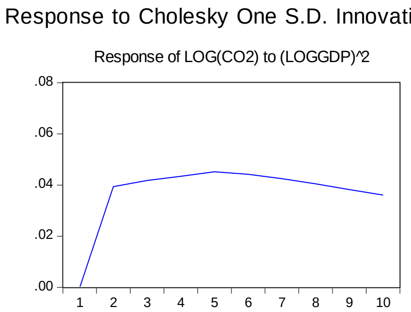
CO_2 response to GDP variable shocks from the first to the 10th period is positive. This is based on the IRF line which is inclined above the horizontal line. After passing 5 periods the

IRF line has increased and is approaching the peak point in the 6th period. The 7th period CO_2 response to GDP shock decreases until the 10th period is shown by a sloping IRF line.



Source: Processed by researchers

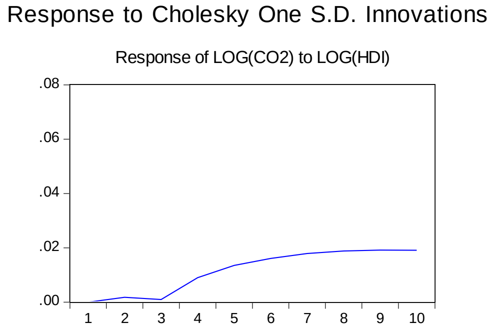
Figure 1. Impulse Response Function CO_2 to GDP



Source: Processed by researchers

Figure 2. Impulse Response Function CO_2 to GDP2

CO_2 to GDP2 in periods 1 to 10 experienced a positive trend based on the IRF which was above the horizontal line. In period 1 to period 5 it shows a positive increase, the peak is in period 5 then the IRF line is sloping.



Source: Processed by researchers

Figure 3. Impulse Response Function CO_2 to HDI

The CO_2 response to the HDI shock increased positively in the 1-10 period as seen by the IRF line above the horizontal line. In the 2nd year the IRF line has increased but the direction of the line is sloping.

The results of the analysis explain that 100% CO_2 is strongly influenced by the variable shock itself in the first period. While GDP, GDP2, and HDI have no effect on CO_2 in the first period. Period 1 to 10, the CO_2 shock contribution is still large. However, CO_2 shock accounts for part of the effect, which gradually reduces to CO_2 itself from period 1 to period 10.

Table 8. Variance Decomposition

Variance Decomposition of LOG(CO_2):					
Period	S.E.	LOG(CO_2)	LOG(GDP)	(LOGGDP)^2	LOG(HDI)
1	0.075874	100.0000	0.000000	0.000000	0.000000
2	0.101926	82.11427	2.947500	14.90803	0.030196
3	0.121002	68.63191	8.845560	22.49484	0.027688
4	0.140132	59.25686	13.94467	26.36357	0.434908
5	0.157759	52.03015	17.89629	28.99834	1.075229
6	0.173214	46.88784	20.80385	30.55619	1.752112
7	0.186660	43.26080	22.82176	31.48977	2.427664
8	0.198232	40.66735	24.19465	32.08548	3.052524
9	0.208160	38.80874	25.10658	32.47149	3.613188
10	0.216713	37.47346	25.68855	32.72713	4.110850

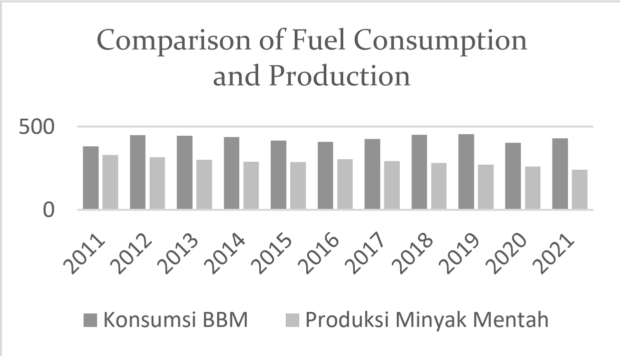
Significant test of 5% in table 5, the t-table value is 2,084. The logGDP t-statistic value is 2.77 > 2.084, so GDP has a partial effect on CO2 in the short term. The t-statistical value of logGDP2 is 2.807 > 2.084, so GDP2 has a partial effect on CO2. While the value of the HDI t-statistic is 0.578 <2.084, then the HDI has no effect on CO2. Estimation of short-term relationships obtained by the following equation model:

$$LogCO2 = (-9.910742\ logGDP) + (0.315464\ logGDP2) \quad (4)$$

GDP and GDP2 variables affect carbon dioxide emissions with respective values α_1 = -9.910742 < 0, α_2= 0.315464 > 0. Based on the results of the analysis of the shape EKC curve (Sun et al., 2022) shows a U-shape of the curve in other words the EKC hypothesis does not apply in the short term. When Indonesia's GDP rises, CO2 will decrease and then will rise again. This is interpreted in order to achieve environmental economic targets as a model that is badly affected in the short term.

The EKC theory in short term is not proven because CO2 emissions are a form of global pollution that fluctuates in the long term. So far, the EKC pollution index does not always follow an inverted U-curve. Taguchi (2013) global pollution of CO2 emissions rejects this theory, but it is different for local pollution of sulfur oxides. The results prove that energy consumption is the main variable in reducing carbon gas. Energy consumption is related to fuel prices as a factor of inflation in the short-term one-year Indonesian economy. EKC does not support it in the short term of this study, accumulating GDP from all sectors that are supportive in the long term.

The average fuel consumption in Figure 4 reaches 426 million per barrel in one year. This was caused by an increase in the number of motorized vehicles which reached more than 133 million units in 2019 (Ministry of Energy and Mineral Resources, 2021). Energy consumption data, especially fuel for the transportation sector, reached 62% of total fuel consumption, while 19% for the industrial sector and household. The average consumption of fuel per month is 50,972 rupiah or around 611,664 rupiah per year based on population expenditure (Zulfikri & Maimunah, 2010). The consequence is that in 2022 there will be an increase in fuel prices to reduce fuel consumption. This is due to a surge in demand that is greater than the production of crude oil so that the solution is to import. This phenomenon causes the government budget to swell due to the increase in world oil prices. Reducing fuel subsidies is a solution to overcome the budget deficit.



Source: (Ministry of Energy and Mineral Resources, 2021)

Figure 4. Fuel Consumption and Crude Oil Production in Indonesia

Based on table 9, the energy consumption level of the industrial sector is 93,363.91 thousand/ BOE per year for coal consumption and is the largest CO2 contributor in Indonesia. The Electrical Energy industry sector is 45,992.3 thousand / BOE per year. More than 38% of the impact of electrical energy on CO2. Sugiawan & Managi (2016) total electricity generation is more than 11%. This value is greater than the recommended average of 8.4%. This results in an excess supply of electrical energy. As a consequence, PJB implemented a policy of reducing electricity subsidies by increasing the electric power from 450VA to 900VA.

Table 9. Data Coal and Electricity Consumption

Year	Coal	Electricity
2011	144.502	33.547
2012	123.022	36.888
2013	42.729	39.466
2014	55.064	40.402
2015	70.228	39.281
2016	63.504	41.773
2017	58.800	44.282
2018	100.506	57.338
2019	167.412	57.794
2020	113.416	54.172
2021	87.820	60.973

Source: Ministry of Energy and Mineral Resources (2021)

In the short term, proving that the EKC hypothesis does not apply, it can be concluded that development analysis in Indonesia is weak in the short term. Nuansa & Widodo (2018) Sustainable development is the complementation of the economic, social and environmental sectors. In the analysis of short-term research results, only the GDP variable as a representation of the economic sector has a significant effect, while the HDI variable does not. Weak sustainability assumes that human resources can replace the role of natural resources (Bashir et al., 2019).

This research is supported (Ali et al., 2015) in Pakistan which proves that there is no relationship between energy consumption and CO_2 in the short term. So that economic growth in Pakistan rejects the EKC curve. The result of similar studies are disclosed by research (Ibrahiem, 2017) EKC curve is not proven because the variables GDP, energy consumption, and trade do not have a significant effect on carbon emissions.

Long-term VECM analysis proves that GDP, GDP2 and HDI have a partially significant effect on CO_2 with a t-statistic value > t table (2.084). The effect of GDP and HDI on CO_2 in the long term occurs because the long term coefficient is higher than the short term. In addition, the elasticity of GDP and HDI is greater in the long run. Sun et al. (2022) estimasi model equation as follows:

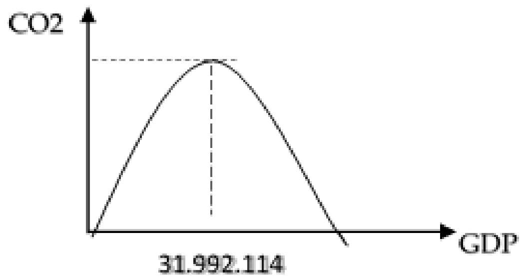
$$LogCO2 = (-20.37718) + (1.925637\ logGDP) + (-0.055713\ logGDP2) + (-3.816086\ logHDI) \quad (5)$$

The *turning point* value is calculated as follows:

$$LogGDP^* = -\frac{\alpha_1}{2\alpha_2} = -\frac{1.925637}{2\ X\ (-0.055713)} = -\frac{1.925637}{0.111426} = 17.281 \quad (6)$$

$$GDP = 31992114\ (on\ 2012).$$

The shape of the EKC curve on the results of the analysis of GDP and GDP2 with the respective values of α_1 is 1.925637 > 0 α_2 is -0.055713 < 0. Based on the results of the analysis the shape of the curve shows an inverted U-shape of the curve, in other words it accepts the EKC curve. The GDP turning point was 31992114, which occurred in 2012. Individually, in lower middle-income countries, when income rises, CO_2 emissions decrease. This is in line with Indonesia in the 2010-2012 period (Nikensari et al., 2019). The results of the analysis show that when GDP rises, CO_2 rises to a point (= 31,992,114), then the increase in GDP is followed by a decrease in CO_2. This shows that community economic activities focus on services and technology as well as environmentally friendly behavior towards activities that can cause externalities. The EKC curve is shown in Figure 5 below:



Source: Data Processed by the author, 2022

Figure 5. The result of Estimation EKC Curve

Forecasting model analysis for 2021-2027 is shown in the following table 10. It is proven that long-term EKC is caused by the characteristics of the research area, Indonesia is a developing country in accordance with the theory of Grossman & Kruger that EKC is proven in lower middle-income countries (Darwanto et al., 2019). This shows that in the long run, there is a linear relationship between economic growth and increased emissions due to the characteristics of the Indonesian state, namely focusing on economic development on increasing income and ignoring environmental damage.

Table 10. Forecasting CO2, GDP, and HDI Period 2021-2027

Year	Projected CO2 (millions tons)	GDP percapita current (lcu)	HDI
2021	532,972,600	59,373,360	73.88
2022	546,026,000	65,995,320	74.64
2023	559,404,600	73,357,910	75.40
2024	573,116,500	81,543,970	76.17
2025	587,169,900	90,645,540	76.95
2026	601,572,700	100,764,900	77.73
2027	616,333,200	112,015,800	78.53

The cause of EKC is proven to be caused by excessive fuel consumption causing limited natural resources so that alternative energy emerges. Victor et al. (2021) Alternative energy has a negative statistical relationship to CO2. The consumption of alternative energy in Indonesia is an important component of economic growth while reducing CO2 emissions (Wahid et al., 2018). The use of alternative energy is a solution to overcome environmental damage without disrupting economic growth as Indonesia's economic growth depends on the oil and gas sector. In addition, Indonesia along with other countries is responsible for environmental damage through commitments in the Paris Agreement on climate change in 2015 (Sugiawan & Managi, 2016).

Based on the results of this research analysis, it shows the Indonesia's sustainable development in the long term is *strong sustainability*. Development that is sustainable development has a complementary relationship between economic, social and economic aspects (Bashir et al., 2019; Nuansa & Widodo, 2018). Shown in the research results GDP, GDP2, HDI have a significant effect by accepting the inverted U-shaped ecc curve. The Environmental Kuznet Curve hypothesis is a Grossman & Krueger study that supports a model that is strong sustainability (Nasrollahi & Saeed, 2018). Strong Sustainability is proven by looking at the rate of increase and decrease of CO2 from 2005-2020 to the next which is smaller than the rate of increase in 1990-2004 assuming normal conditions.

This research in line with (Sarkodie & Strezov, 2019) with the EKC hypothesis applies in Indonesia with turning point US$ 2999. Developing countries strive to achieve sustainable development with incoming foreign investment bringing clean technology and good workforce management. Munir et al. (2020) the results of the study show support for the EKC in 5 ASEAN countries including Indonesia. HDI's research on CO2 is in similar with (Mahmood et al., 2019) which demonstra-ted that there is a bidirectional relationship between CO2 emissions and HDI. Humans are an effective effort in reducing CO2 emissions through R&D programs. However, this research is contradictory (Rezeki et al., 2022) Increasing the quality of HDI will increase pollution resulting from an increase in population so that the fulfillment of their needs will also increase without being offset by the regeneration of natural resources to fulfill needs. This results in industrial capitalism which causes negative externalities.

CONCLUSION

The quantitative study of the VECM model on the short-term analysis of sustainable developpment in Indonesia is weak sustainability and the U-shaped EKC curve, in other words, rejects the EKC hypothesis. GDP variable, GDP2 has an effect on CO2, while HDI has no effect. This is due to increased energy consumption in the short term. Whereas in the long-term sustainable development in Indonesia is strong sustainability accepting the EKC hypothesis with an inverted U-shaped curve. The variables GDP, GDP2, and HDI have a significant effect on CO2. This is due to the transform manufacturing to the service sector and environmentally friendly technology and alternative energy as a way to reduce dependence on fuel, as Indonesia and other countries have committed to reducing carbon emissions in order to achieve sustainable development in the long term.

Researchers' suggestions to the government in reducing carbon gas are carried out by industrialization processes that are green economic. The government is going through a tax holiday to attract FDI that enters Indonesia with an environmentally friendly production process as a requirement. Carry out carbon tax costs to business actors as a form of negative externality costs. Apart from that, increasing alternative energy sources as a substitute for fuel oil and increasing capacity to meet regional energy needs. Indonesia has potential and natural resources that have the potential to become alternative energy such as hydropower, nuclear, biofuel from palm oil. Increasing HDI in reducing pollution through educational policies and environmentally friendly teaching curricula implemented through learning institutions. In addition to providing socialization to the community to care about the environment.

Suggestions for further research by determining variables that describe EKC on pollution are important. Subsequent research variables include other types of environmental indicators such as sulphuroxide, carbon monoxide, nitrogen dioxide which pose a hazard to human health and the environment. In addition, they describe past and present economic phenomena specifically and accurately. Continue the quadratic direction of the EKC with the addition of GDP3 to see if the EKC is N-shaped or inverted.

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