Journal of Socioeconomics and Development

https://publishing-widyagama.ac.id/ejournal-v2/index.php/jsed

Existence of the Environmental Kuznets Curve and its relevance to SDGs policy: A study in Java region, Indonesia

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ARTICLE INFO

►Research Article

Article History
Received 14 April 2022
Accepted 9 May 2022
Published 1 September 2022

Keywords
CO2 emissions; economic growth; Environmental Kuznets Curve; panel data

JEL Classification
Q01; Q11; R11

ABSTRACT

The debate on economic growth as a trigger or solution to environmental damage is the driving force behind this research. This study examines whether there is an advanced stage of the Environmental Kuznets Curve (EKC) that forms a curve resembling the letter N in Java province, Indonesia. This study used a panel data regression model with the main variableof CO2 emissions and GDP per capita. This research demonstrated that, in the short term, per capita income growth caused damage to the environment. However, this relationship was different in the long run and eventually formed an N-shaped curve. The existence of an N-shaped EKC was detected, but not significant. The relationship between population growth rates, income inequality and the Sustainable Development Goals (SDGs) with CO2 emissions as well as EKC turning points were also investigated in this study. The study results included N-shaped EKC detected in Java with the first turning point of Rp 154,297,936 and the second turning point of Rp 1,136,629,791. Population growth rate was proven not to affect CO2 emissions, in contrast to income inequality and the SDGs agreement which affected emissions in Java. Raising public awareness, paying attention to energy use, initiating technological innovations, and enforcing pro-environment policies are recommended to be implemented in Java and across Indonesia.

To cite this article: Ibrahim, M. D. & Abbas, M. H. I. (2022). Existence of the Environmental Kuznets Curve and its relevance to SDGs policy: A study in Java region, Indonesia. Journal of Socioeconomics and Development, 5(2), 162-174. https://doi.org/10.31328/jsed.v5i2.3657

ISSN 2615-6075 online; ISSN 2615-6946 print

INTRODUCTION

Changes in the environment and world climate have the potential to cause catastrophic consequences for human survival. Climate change is the most severe environmental threat facing humans today (Wang et al., 2021) as well as a complex social challenge (Kalele et al., 2021). In the last five decades, the global climate system has undergone significant changes with high frequency and impact of extreme weather (Kalele et al., 2021; Li et al., 2021).

Climate change is driven by a large number of factors, but greenhouse gas (GHG) emissions are one of the key contributing factors (Yue & Gao, 2018). To a certain extent, GHG emissions are needed by the earth, but will cause climate change if they are too excessive (Özokcu & Özdemir, 2017). CO2 emissions are one of the components of GHG often used as research references and environmental indicators since, although not the largest contributor to GHGs, many CO2 emissions originate from human activities (IPCC, 2014; Özokcu & Özdemir, 2017; Septiana, 2013; Suharto et al., 2021).

Economic growth generated by exploiting nature is frequently accused of causing environmental degradation. Economic interests often collide with environmental preservation as indicated by numerous studies, one of which is the Environmental Kuznets Curve (EKC) hypothesis. The hypothesis rejects the opinion that economic factors bring damage to the environment (Özokcu & Özdemir, 2017). The curve of the hypothesis demonstrates that environmental issues can be solved in the long run with economic growth, despite environmental degradation at the beginning of economic development (Sugiawan & Managi, 2016). The EKC hypothesis illustrates that there is an inverse U-shaped relationship between environmental degradation and economic growth.

The curve was named the Environmental Kuznets Curve due to its similarity to the Kuznets Curve which explains the inverse U relationship between income inequality and economic growth initiated by Simon Kuznets (Özcan & Öztürk, 2019; Özokcu & Özdemir, 2017). The inverted U shape in the EKC hypothesis occurs since environmental degradation will increase at the beginning of development to a certain point, commonly called a turning point. With increasing income as an indicator of economic growth, a turning point will be reached and the environmental degradation begins to decrease along with increasing income (Ahmad et al., 2017; Alam et al., 2016; Özokcu & Özdemir, 2017; Sugiawan & Managi, 2016; Tatoğlu & Polat, 2021; Uchiyama, 2016).

In EKC, the development phase isdivided into three stages, namely the pre-industrial, the industrial and the post-industrial phase (Özcan & Öztürk, 2019). In the early stages of development or pre-industrial, environmental degradation increases because people are less concerned about environmental impacts. However, upon entering the industrial phase, people are more concerned with facilities that produce less pollution to the environment (Özcan & Öztürk, 2019). Subsequently, in the post-industrial stage, economic growth is followed by a decrease in environmental degradation. According to Dinda (2004), higher economic growth and income generally drive higher demand for environmental quality.

The aforementioned stages of development are in line with a study by Grossman et al. (Özcan & Öztürk, 2019) which stated that environmental quality is influenced by economic activities in three ways, namely scale effects, composition effects and technique effects. In the effect of scale, the growth of economies of scale results in a high increase in environmental pollution since many resource inputs are exploited in production instead of environmental management (Tatoğlu & Polat, 2021). Subsequently, the composition effect describes the inverse U relationship. Slong terectoral structural changes occur at this stage, where low-income countries change from agriculture-oriented to industry-oriented which drive environmental pollution, while high-income countries shift from industry-oriented to service-oriented sectors with low pollution intensity (Özcan & Öztürk, 2019). In the technical effect, technological modernization occurs by changing technology to be better and cleaner which can improve environmental quality (Dinda, 2004).

This study examines whether there are advanced stages of inverted U-shaped EKC, referring to the research of Balsalobre-Lorente et al. (2018), Dinda (2004), Özokcu & Özdemir (2017), as well as Uchiyama (2016), using the analysis of cubic EKC specifications on economic growth and potentially depicting the N-shaped EKC curve. This N-shaped relationship refers to a study by Dinda (2004) which states that an inverted U-shaped EKC is not permanent. The decrease in environmental degradation is temporary and generally increase to form an N-shaped curve. The N-shaped relationship occurs because the technical effects of improving the environment through technology has become increasingly ineffective. Álvarez-Herránz et al. (2017) and Sinha et al. (2019) refer to this phase as "technical obsolescence" or obsolescence of the technical effects that encourages the increase in CO2 emissions to reoccur. Research on the validation of N-shaped EKC was conducted by Uchiyama (2016) in 171 countries during the period of 1960-2010, validating the existence of N-shaped EKC. Similar results were obtained by Balsalobre-Lorente et al. (2018) in five European Union countries in 1985-2016 as well as by Özokcu & Özdemir (2017) in 26 OECD countries in 1980-2010.

Recently, EKC has been widely studied with environmental indicators, economic indicators, explanatory variables, countries, time periods and different econometric techniques. Ersin (2016) examined the relationship between the presence of EKC in 13 developed countries in 1870-2011 and validated the existence of EKC. Similar results with the panel data model were also obtained by Le & and Quah, (2018), Nikensari et al. (2019), and as well as Tatoğlu & Polat (2021) with the same environmental indicator, i.e. CO2 emissions. In addition to the hypothesis of an inverted U-shaped EKC, the study results of Uchiyama (2016) as well as Özokcu & Özdemir (2017) using a data panel model validated the existence of an N-shaped EKC by adding the cubic GDP variable to the calculation. However, different results were obtained by P. Y. Chen et al. (2016) for 188 countries in 1993-2010, Apergis & Ozturk (2015) in 14 Asian countries, Noor & Saputra (2020), and Vo et al. (2021) in 26 countries that do not demonstrate the existence of EKC. In a narrower scope, that is Indonesia, there are several studies indicating contradictory results. Alam et al. (2016) used the ARDL method to validate the existence of EKC in Indonesia. However, different results by Ridzuan et al. (2020) using the ARDL method and Noor & Saputra (2020) using 2SLS Regression failed to validate the existence of EKC in Indonesia. These results indicate that the existence of EKC is different in each scope of research and is still biased, especially with the differences in research methods, countries studied, time span, and environmental and economic indicators. The turning point of EKC also varies in each study and the majority is still in high numbers.

In addition to economic growth, there are two other variables examined in relation to CO2 emissions, namely population level and income inequality. Population level is added considering that larger human population encourages high energy demand, resulting in the potential for increased pollution (Alam et al., 2016; Apergis & Ozturk, 2015; Nikensari et al., 2019; Tatoğlu & Polat, 2021). Moreover, Indonesia is the fourth most populous country in the world (World Bank, 2021a) which still heavily depends on unclean energy resources. Also, Indonesia's fast-paced economy has resulted in the change in social and economic structures, including the increasing income inequality pattern. Low income inequality has been studied to help control emissions (P. Y. Chen et al., 2016; Jorgenson et al., 2017; Zhang & Zhao, 2014).

This study also relates the phenomenon of environmental degradation and economic growth, especially in EKC, with sustainable development. The EKC concept presents a very close relationship with sustainable development. According to Uchiyama (2016), the concept of EKC is very closely related and is interesting in the discussion of sustainable development since it is used to understand the effect of economic growth on the environment. In the concept of sustainability, economic development must be carried out while paying attention to conservation efforts to ensure that its benefits are preserved for future generations (Gupta & Dharwal, 2022; Sugiawan & Managi, 2016). The three main aspects in sustainable development include economic growth, environmental preservation, and social progress (Gupta & Dharwal, 2022; Suharto et al., 2021). Sustainability is promoted not only in a small scope, such as the state, but also worldwide by the United Nations (UN). The UN has established an agenda of Sustainable Development Goals (SDGs) which include 17 main goals with 169 targets (UN, 2016). In general, the SDGs aim to improve the quality of human life, increase prosperity and protect the planet (Scherer et al., 2018). The SDGs are expected to be a guide for countries in decision-making and development policies.

Environmental degradation is an urgent problem for sustainable economic development, especially for developing countries relying on natural resources to sustain their economy. Indonesia is one of the ten largest emitting countries in the world (Friedrich et al., 2020) and Java accounted for 53% of Indonesia's emissions in 2019. This occurs because many industries are oriented in Java, causing numerous environmental effects. One of the examples is the existence of thermal power stations as a source of electricity. Electricity consumption in Java has tripled compared to regions outside Java in 2020 (National Electricity Company, 2021). Previous literatures did not indicate evidence of the validity of EKC, especially in Indonesia and Java, and no available studies identified the inflection points for EKC in Indonesian and Javanese subjects.

The study mainly aims to examine the validity of the EKC in Java before and after the approval of the SDGs. It also aims to link the EKC concept with the SDGs and to investigate whether there is a real movement from Indonesia that leads to a sustainable development path. Inflection points are also investigated in this study. This research offers to contribute to the study of the impact of economic and social factors on the environmental degradation in Java. In addition, this research potentially contributes to the sustainable economic development and policy making in Java. This study examines the amount of income that describes the turning point and adds the number of population and income inequality in the calculation to determine the effect of these two variables on Indonesia's CO2 emissions.

RESEARCH METHOD

This study used panel data combining cross-section and time series data in Java region. It employed panel data in 2011-2019 in the provinces of DKI Jakarta, West Java, Central Java, East Java, Yogyakarta, and Banten. The time span of 2011-2019 describes the period of before and after thesetup of the Sustainable Development Goals (SDGs).

EKC hypothesis testing is operated by economic and environmental degradation indicators, such as GDP per capita and CO2 emissions. GDP per capita data used is based on 2010 constant prices divided by the total population of each province taken from the Indonesian Central Statistics Agency. Meanwhile, the CO2 emissions is the amount of carbon emissions in each province obtained from the Ministry of Environment and Forestry.

This study used such analysis method as the Autoregressive Distributed Lag (ARDL) based on time series data, as suggested by Alam et al. (2016), Ali et al. (2017), Kusumawardani & Dewi (2020), Ridzuan et al. (2020), Sugiawan & Managi (2016), and Vo et al. (2021); and panel data regression models (Ersin, 2016; Le & Quah, 2018; Nikensari et al., 2019; Tatoğlu & Polat, 2021).

The majority of previous studies used quadratic equations to determine the inverted U pattern of EKC, but this study used cubic equations to test whether there is an advanced stage of the inverted U pattern of EKC, referring to Dinda (2004), Özokcu & Özdemir (2017), and Uchiyama (2016). According to Özokcu & Özdemir (2017), the cubic equation is used to examine whether there is an inverse trend after the reduction in environmental degradation caused by increased income. The equation can be written as follows:

$$CO2_{it} = a + \beta_1 GDP_{it} + \beta_2 GDP2_{it} + \beta_3 GDP3_{it} + \beta_4 POP_{it} + \beta_5 INEQ_{it} + \beta_6 SDGS_{it} + e_{it} \quad (1)$$

The variables in this study included CO2 emissions (CO2) as the dependent variable, while GDP per capita (GDP), GDP per capita squared (GDP2), and GDP per capita cubic (GDP3) were the independent variables (Table 1). The quadratic and cubic equations on the GDP per capita variable were used to observe the relationship between environmental degradation and economic growth in the form of a curve. According to Özokcu & Özdemir (2017), the cubic equation is used to examine whether there is an inverse trend after the reduction in environmental degradation caused by increased income. Population level (POP), income inequality (INEQ), and SDGs were also added as explanatory variables. The addition of the population growth rate variable referred to the studies of Alam et al. (2016), Apergis & Ozturk (2015), Nikensari et al. (2019), and Tatoğlu & Polat (2021), while the addition of income inequality variable referred to the studies of Chen et al. (2020), Grunewald et al. (2017), Hao et al. (2016), Jorgenson et al. (2017), Kusumawardani & Dewi (2020) as well as Zhang & Zhao (2014). Equation (1) also used the dummy variable SDGs (SDGs) to determine the effect of the SDGs agreement on CO2 emissions (0=before SDGs, 1=after SDGs).

Prior to the Equation 1 calculation, Chow Test, Hausman Test, and Lagrange Multiplier Test were carried out to determine the most suitable model among Common Effect Model (CEM), Fixed Effect Model (FEM), or Random Effect Model (REM). Subsequently, classical assumption test was carried out using the multicollinearity test and the heteroscedasticity test. After Equation 1 calculation was carried out, result interpretation was performed through t-test, f-test and coefficient of determination or R-square test. The t-test was done to determine the coefficient of the independent variable on the independent variable partially, and the f-test was conducted to determine whether all the independent variables were able to explain the dependent variable simultaneously.

Table 1. Descriptive Statistics of Variable

Variable	Symbol	Observation	Mean	Min.	Max.	Std. Dev.
CO2 Emission (x1000 tons CO2)	CO2	54	68,806.99	4,632.40	392,393.40	64,654.62
GDP per capita (million rupiahs, Rp)	GDP	54	47.10	19.39	173.92	44.75
Population growth rate (%)	POP	54	1.17	0.49	2.39	0.54
Inequality income (Gini index)	INEQ	54	0.40	0.36	0.44	0.02
SDGs (dummy)	SDGs	54	0.44	0.00	1.00	0.50

The calculation of the turning point or EKC peak point was then conducted to determine at which point per capita income CO2 emissions began to decline. Research on this cusp has yielded mixed results. According to Bhattacharya (2019), there is no agreement in the literature regarding the level of income where the turning point occurs. Although there is no definite turning point, Uchiyama (2016) stated that the EKC turning point was at US$15,698 to US$16,595 (constant 1990 prices) for a sample of OECD (Organization for Economic Co-operation and Development) countries, and between US$15,600 and US$21,186 for the non-OECD sample. Since this study used a cubic equation, two inflection points were generated. The formula to determine two N-shaped EKC inflection points referred to Diao et al. (2009) as follows:

$$x_1 = \frac{-b_2 + \sqrt{{b_2}^2 - 3b_1b_3}}{3b3}$$

$$x_2 = \frac{-b_2 - \sqrt{{b_2}^2 - 3b_1b_3}}{3b3}.$$

$$CO2_{it} = a + \beta_1 GDP_{it} + \beta_2 POP_{it} + \beta_3 INEQ_{it} + \beta_4 GDP * DM_{it} + \beta_5 POP * DM_{it} + \beta_6 INEQ * DM_{it} + e_{it} (2)$$

Another equation was also used in this study, namely Equation 2, which aimed to identify the different effects of independent variables (GDP per capita, population rate, and inequality) on CO2 emission variables before and after the SDGs establishment by adding a dummy variable (DM) to each independent variable. Equation 2 used an ex post facto method to observe changes in the influence of the independent variables, namely income per capita, population growth rate and income inequality after the SDGs agreement at the end of 2015.

RESULT AND DISCUSSION

Characteristics of Respondent

Provinces in the island of Java were used as the subjects of this research, i.e., DKI Jakarta, West Java, Central Java, East Java, Yogyakarta and Banten. Java was selected since it is the center of the economy, state administration and politics in Indonesia. The capital city of Indonesia is also located in Java. Economic mobility is significantly high in Java and many large industries are located in Java. The provinces in Java dominate the structure of the Indonesian economy with a percentage of 57.89% (Central Bureau of Statistics, 2022). The total population of Java Island is also extremely large when compared to regions outside Java with a percentage of approximately 56%, even though the area of Java is smaller than other islands in Indonesia.

The industrial economic activities and population distribution in Java have various impacts, one of which is CO2 emissions. Industrial pollution and high energy use drive high levels of CO2 emissions, especially in provinces with a large population. In 2019, Indonesia's total CO2 emissions amounted to 729,902.41 thousand tons of CO2, where Java was the highest contributor with a percentage of approximately 53% (MEF, 2022). In Java, East Java Province's emissions outperformed other provinces in the last three years as presented in Table 2.

Table 2. CO2 Emissions of Provinces in Java

Region	2017	2018	2019
	....	x1000 tons CO2	....
DKI Jakarta	28,285.58	32,689.45	38,578.96
West Java	72,893.13	69,956.31	123,688.11
Central Java	99,190.25	82,758.28	91,901.66
East Java	126,729.94	195,769.92	3922,393.37
Yogyakarta	12,378.06	4,632.01	5,285.50
Banten	100,330.18	18,256.78	78,054.81

Source: MEF (2022)

According to Sugiawan & Managi (2016) Indonesia remains dependent on fossil fuels. Oil, coal, and gas resources are the three largest energy resources in the country. Energy resources derived from fossils are the supporter of the electricity sector in Indonesia. Coal is the largest source of power generation with a percentage of 56.4% in 2018 (Secretariat General of National Energy Council, 2019). In Java, the use of coal fuel for the electricity sector is extremely high, three times higher than the use outside Java in 2020 (National Electricity Company, 2021). This is due to the high demand and consumption of electricity in Java, which affects the amount of electricity production and in turn has an impact on increasing CO2 emissions.

Variables Affecting CO2 Emission

There are three commonly used panel data regression models, namely the Common Effect Model (CEM), Fixed Effect Model (FEM) or Random Effect

Model (REM). The Chow test and Hausman test indicated that FEM was the most suitable model in this study. The results indicated that the FEM model was better than the CEM as illustrated in the results of the Chow test with a probability (Prob.) of 0.0055 or Prob. <0.05, suggesting that H0 is rejected and H1 is accepted or that FEM is a better model. To determine whether the Fixed Effect Model (FEM) or the Random Effect Model (REM) was the better model, the Hausman test was performed. The result indicated a probability value of 0.0002 or Prob. <0.05, suggesting that H0 is rejected and H1 is accepted or FEM proves to be a better model than REM. Fixed Effect Model (FEM) is the most suitable estimation model since it espouses the research objectives and has the highest and significant Adj-R for all independent variables.

Classical assumption testing was also carried out and the results indicated that there was a heteroscedasticity problem in the study. The Breusch-Pagan/Cook-Weisberg test method was used to test for heteroscedasticity. The results demonstrated that indeed there was a heteroscedasticity problem in this study. The probability value of 0.0000 indicated the existence of the problem. To overcome the issue, the Generalized Least Squares (GLS) regression model can be used to prevent heteroscedasticity to obtain an unbiased, consistent and efficient estimate (Setyawan et al., 2019). The following is a table of data estimates using Generalized Least Squares with observations in the provinces in Java during the 2011-2019 period. The F-test in this study resulted in an F-statistical probability value of 0.0000 at a significance level of 5%. This suggests that the independent variables, namely GDP, population growth rate, income inequality and SDGs agreement, have an effect on the CO2 emission variable in Java.

Population growth rates, income inequality, as well as the SDGs were also examined in this study. It was discovered that population growth rate did not significantly have a positive relationship with CO2 emissions. Meanwhile, income inequality, as reflected in the Gini coefficient and the SDGs agreement, had a negative relationship with CO2 emissions at a significance level of 0.1.

Based on the results of the regression calculations, only the GDP variable was statistically significant at the 0.01 level. These results indicated that an increase in per capita income affects the intensity of CO2 emissions.

Table 3. Estimate Variables Affecting CO2 Emission

Variable	Coefficient	Standard Error	Sig. Level
GDP	15878.01	5335.057	0.003
GDP2	-58.43732	64.86891	0.368
GDP3	0.0301784	0.2286611	0.895
POP	2128.771	21146.49	0.920
INEQ	-851768.5	442637.2	0.054
SDGs	-42077.18	18705.72	0.024
Constant	-754729.6	290667.7	0.009

There was a significant positive relationship between per capita income and CO2 emissions. The increases per capita income is proven to improve environmental degradation. Economic growth that requires resources and produces waste remains a problem in developing countries such as Indonesia. In addition, there is no strict regulation and adequate green technology to reduce the economic impact on the environment. However, the positive relationship between per capita income and CO2 emissions is bound to change in the long run. The results of this study indicated the existence of an N-shaped EKC.

Meanwhile, the population level had an insignificant positive effect on CO2 emissions in Java. This is not in line with research conducted by Alam et al. (2016), Apergis & Ozturk (2015), Nikensari et al. (2019) and Tatoğlu & Polat (2021), which proved that there is a significant effect between population and CO2 emissions. Although no significant effect was observed, the policy on population growth must still be carried out seriously. This is because Indonesia's population continues to increase every year, making it the fourth most populous country in the world. The increasing population each year has the potential to cause high CO2 emissions in Indonesia since an increase in population generally leads to high energy demand which drives greater pollution, especially when Indonesia remains dependent on unclean or non-renewable energy sources. This is in line with a study by Hashmi & and Alam (2019) which stated that population is the main factor driving high CO2 emissions. Even the research shows that the impact of regulation and technology is not able to offset the impact of population in reducing CO2 emissions.

The income inequality variable in this study was described by the Gini coefficient and had a significant negative effect on CO2 emissions. This negative result is in line with the research of Hao et al. (2016) as well as Kusumawardani & Dewi (2020), suggesting that income distribution tends to increase CO2 emissions. Income distribution can be identified in two ways, namely an increase in the income of the poor and a decrease in the income of the rich. According to Grunewald et al. (2017), efforts to reduce inequality through income redistribution generally increase CO2 emissions. Equity with an increase in the income of the poor will cause the community groups to consume more energy which results in increased energy consumption and increased CO2 emissions as a consequence (Kusumawardani & Dewi, 2020). Likewise, the income distribution of the rich towards lower income groups will change the consumption pattern of the rich from low-polluting goods to high-polluting goods since high-polluting goods tend to be cheaper than low-polluting goods.

The N-shaped EKC

Furthermore, from the coefficient values of GDP, GDP2 and GDP3, it is shown in Table 3 that there is an N-shaped EKC curve that refers to the studies of Dinda (2004) and Özokcu & Özdemir (2017), which is in accordance with the conditions β_1>0, β_2<0, and β_3>0. Therefore, with this calculation, it can be said that the N curves were detected, but were not significant (prob. GDP2, GDP3 > 0.05). This means that there is an advanced stage of the inverted U-shaped EKC curve. With this result, it can also be interpreted that there are two inflection points on the EKC.

The two turning points being examined in this study were the first and the second turning points. The calculation of these two income level points referred to the study of Diao et al. (2009). The first turning point describes the level of income at which environmental degradation begins to decrease. The first turning point obtained in this study was Rp 154,297,936. Subsequently, the second turning point that occurs was examined due to the "technical obsolescence" that cause an increase in CO2 emissions reoccur in Java. This study indicated that the second turning point in this study was Rp 1,136,629,791. This means that there will be a decrease in environmental degradation if Java's per capita income is at Rp 154,297,936. However, the reduction in environmental degradation is temporary and will result in technical obsolescence at the income level of Rp 1,136,629,791, at which level the environmental degradation increases again.Hence, an N-shaped curve can be drawn, or it can be said that an N-shaped EKC is detected in Java (Figure 1).

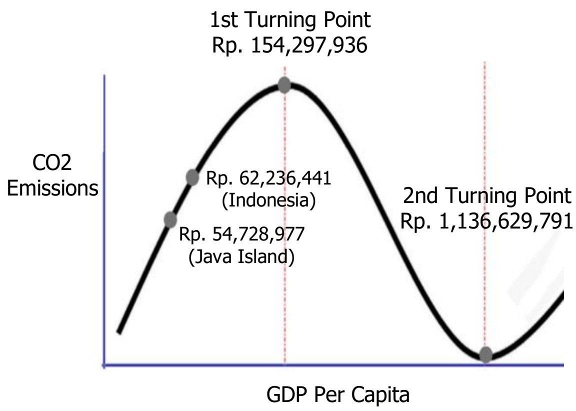

Figure 1. Illustration of the N-shaped EKC

The results of the analysis show an N-shaped pattern was present in the relationship between CO2 emissions and GDP in Java in 2011-2019. This study identified a temporary decrease in environmental degradation and reoccurrence of increase to form an N-shaped curve. This N-shaped curve suggests that there is an indication of insufficient environmental improvement (Özokcu & Özdemir, 2017). Álvarez-Herránz et al. (2017) and Sinha et al. (2019) referred to this condition as "technical obsolescence" or obsolescence of technical effects that cause an increase in CO2 emissions to reoccur at a certain income point. This can happen since the initially high public awareness of the environment begins to decline over time and the scale effect becomes more dominant (Lorente & Álvarez-Herranz, 2016). The scale effect is the initial condition of the EKC hypothesis where the growth of economies of scale results in a high increase in environmental pollution since many inputs are exploited in production instead of environmental management (Tatoğlu & Polat, 2021). The results of this N-shaped EKC study are similar to those obtained by Uchiyama (2016) in 171 countries during the 1960-2010 period, followed by the study of Balsalobre-Lorente et al. (2018) in five European Union countries during 1985-2016, as well as Özokcu & Özdemir (2017) in 26 OECD countries from 1980 to 2010. The results of this study illustrate that a policy that can delay technical obsolescence is needed in the long term.

Studies on N-shaped EKC also showed different results. The findings are different from the findings of the study by Uchiyama (2016), which indicated turning points of US$15,698 to US$16,595 (constant 1990 prices) for the sample of OECD countries. A study by

Balsalobre-Lorente et al. (2018) identified the first inflection point at a value of US$29,647.48 and the second inflection point of US$38,534.87. Bhattacharya (2019) argued that there is no agreed value or definite value at the turning point of the EKC study. Certain countries may also not be generalizable in EKC studies. Differences in environmental indicators, time spans, regional conditions and variables also lead to inconsistent turning points of the EKC. The findings also indicate that the turning point of Indonesia's EKC remains relatively far from being achieved considering that its GDP per capita currently stands at Rp 62,236,441 or equivalent to US$4,349.5 and the GDP per capita of the provinces in Java at Rp 54,728,977 or equivalent to US$3,824 (Central Bureau of Statistics, 2022) as illustrated in Figure 1. These results show that Java and Indonesia are far from reaching the first turning point, a phase where economic growth can improve the environment.

The stages of decreasing environmental degradation and the current value of income in Java have not reached Rp 154,297,936, the first inflection point. According to Nikensari et al. (2019), the estimated value of income which is predicted to be able to reduce CO2 emissions must be balanced with the ability of the country itself. Various aspects must be taken into serious consideration and given proper attention. Otherwise, CO2 emissions will not decrease even though the estimated revenue value has been reached.

CO2 Emissions and SDGs Policy

The effect of the SDGs agreement was also investigated in this study. Table 4 shows the results of the calculations in Equation 2 and indicates that each variable presented a different influence during the 2011-2019 period and after the establishment of SDGs. GDP per capita, which initially indicated a positive effect on CO2 emissions during 2011-2019, subsequently indicated a negative effect on CO2 emissions. Similarly, changes in the coefficient also occurred in the income inequality variable. Meanwhile, the population growth rate variable did not experience a change after the establishment of SDGs.

The results indicated that the United Nations' SDGs, which was declared at the end of 2015, is proven to be able to reduce the level of CO2 emissions, suggesting that Java and Indonesia's performance is relatively satisfactory and the movement in achieving the 17 goals in the SDGs is promising. SDGs are a manifestation of the United Nations' effort to advocate sustainable development agenda for its member countries.

Table 4. Estimate Variables Affecting CO2 Emission Before and After the SDGs Policy

Variable Independent	Coefficient (before SDGs policy)	Variable Independent (with dummy)	Coefficient (After SDGs policy)
GDP	4.023068	GDP*DM	-372.3948
POP	-24888.54	POP*DM	-29501.28
INEQ	-1396588	INEQ*DM	155862.3

This study also identified changes in the effect of per capita income, population growth rate and income inequality after the establishment of SDGs on CO2 emissions with calculation results presented in Table 4. It can be observed that independent variables had different effects on CO2 emissions. After the establishment of SDGs, increasing GDP per capita reduces CO2 emissions. These results indicate that there is a commitment to reduce CO2 emissions and efforts to reduce global warming. This analysis is in line with the findings in Equation 1 in that the SDGs have an influence in reducing CO2 emissions in Java. Various policies issued in the period after the establishment of SDGs appear to present a good influence in reducing CO2 emissions, including the National Action Plan for Climate Change Adaptation. With increasingly stringent regulations and the implementation of RAN-API, it is not impossible that this trend will continue. However, in accordance with these results, it is worth noting that CO2 emission reductions is not permanent and that monitoring and policy enforcement are required to keep the trend on the right track.

Table 4 demonstrates that income inequality also has a positive effect on CO2 emissions, which suggests that after the establishment of SDGs, high income inequality increases CO2 emissions. This positive influence is due to several factors, including the political factor and the power of the rich (Jorgenson et al., 2017). It stated that rich people with ownership of environmentally unfriendly companies often gain political power and dominate environmental policies with the influence they have. On the other hand, the poor will bear the environmental consequences and costs. Meanwhile, there is no difference in the effect of the population growth rate on CO2 emissions before and after the establishment of SDGs.

This study indicated that there are contradictions if the EKC concept is linked to the SDGs. Practically, there are two conflicting sides when connecting economic development with environmental quality. Goals related to economic growth, such as no poverty (SDG No. 1), no hunger (SDG No. 2), decent work and economic growth (SDG No. 8), and industry, innovation and infrastructure (SDG No. 9) are on one side, namely the goals in economic growth. On the other side are goals in environmental interests, such as clean water and sanitation (SDG No. 6), affordable and clean energy (SDG No. 7), sustainable cities (SDG No. 11), climate actions (SDG No. 13), ecosystems in water (SDG No. 14) and ecosystems on land (SDG No. 15).

Existing economic interests are often contradictory and sacrifice items on the other side of the goals. The contradiction between these two sides are more clearly seen if implemented in developing countries with economic dependence on their resources, for example the foreign direct investment (FDI). FDI is indeed the engine of economic growth in developing countries (Guzel & Okumus, 2020) and has various positive impacts on the economic sector such as reducing poverty and increasing employment, which in turn increases a country's economic growth. On the other hand, FDI has the potential to damage the environment through the negative externalities it creates, in addition to the fact that most of the investments made in developing countries are in the primary and secondary sectors. This condition is called the Pollution Haven Hypothesis (PHH). Research on PHH conducted by Guzel & Okumus (2020) proved that this phenomenon is evident in ASEAN countries, including Indonesia. This finding indicates that FDI in ASEAN countries has a negative effect on environmental quality and the Pollution Haven Hypothesis occurs in these countries. The environmental regulations of developing countries that are less stringent than those of developed countries are the reason for the occurrence of PHH, hence many companies invest in developing countries.

In dealing with the contradictions between the two aforementioned sides and the problems of PHH in developing countries, there are two SDGs points that can reduce the impact of existing contradictions, namely responsible consumption and production (SDG No. 12), and peace, justice and strong institutions (SDG No. 16). Responsible consumption and production leads to integrated waste management and consumption that is not excessive or based on the 3R concept (Recycle, Reuse and Reduce), while strong institutions can be useful to avoid illicit investments that cause environmental damage. Delimitation the scale of investment and promoting clean energy investment can also be carried out to minimize negative environmental impacts. Another suitable suggestion includes a tax incentive policy for investments using high technology with low energy intensity (Guzel & Okumus, 2020).

Research Implication

The results of this study suggest the presence of N-shaped EKC in Java, indicating that increase in environmental degradation will reoccur in the long term as in the early stages of development or technical obsolescence. The policy implication of the study results is that optimizing economic growth is one of the requirements to preserve the environment. The most certain form or effort to restore environmental degradation and damage that has been caused is to become a prosperous country or to become a country that is financially able to restore the environment. However, several views suggested that environmental improvement cannot be achieved by certain countries since their living standards or economy are far below the estimated turning point, which in the study refers to the first turning point. Achieving the status of a prosperous country takes a lot of time and resources. To do so, high economic growth is needed every year, but it must be supported by strong institutions in order to keep development within the sustainable corridor.

It is necessary to formulate and enforce policies with a long-term impact such as technological innovation. The process of reducing CO2 emissions with low-carbon technological innovations can create a scale effect or resource exploitation since the growth of economies of scale is not too dominant and technical obsolescence can be delayed (Aghion et al., 2019; Álvarez-Herránz et al., 2017). Technological innovation is needed by many countries presently and in the future, for example technological innovation in the production and disposal of industrial sector waste in Indonesia. Waste is still an issue in Indonesia, especially plastic waste. Approximately 7.8 million tons of plastic waste are produced annually in Indonesia and 4.9 million tons of them are not properly managed (World Bank, 2021b). In terms of waste management, it is therefore recommended to initiate technological innovations and start a circular economy (CE) aiming to prevent excessive plastic pollution. CE is a form of effort to reduce environmental degradation and waste management in realizing sustainable development. In line with research by Sharma et al. (2021) and Ogunmakinde et al. (2022), waste management in the form of CE must be prioritized in achieving the SDGs. Furthermore, Ogunmakinde et al. (2022) argued that CE covers 10 of the 17 main goals in the SDGs. Another study conducted by Xue et al. (2019) declared that CE can reduce GHG and carbon emissions since the utilization and management of waste minimizes CO2 emissions.

Maintaining sustainable economic growth, formulating pro-environment policies, maximizing the use of new and renewable energy and increasing public awareness are other measures that are important to enforce. Maintaining a balance between economic and environmental interests can be accomplished by creating policies that are not only oriented to the economy but also to the environment. Subsequently, the promotion of new and renewable energy resources must also be carried out collectively by the government and people to reduce the use of fossil-based energy resources such as oil, coal and gas which remain Indonesia's mainstay. Increasing public awareness of the environment is equally important. It must be established starting from the scope of individuals, households, companies, and the state. Increasing environmental quality cannot be separated from public awareness such as awareness of the use of low polluting goods and regular use of energy.

In terms of environmental policy, the government of Indonesia established the National Action Plan for Reducing Greenhouse Gas Emissions in 2011 and the National Action Plan for Climate Change Adaptation in 2014 as the commitment in dealing with the environment and climate problems. Indonesia has set a target of reducing GHG emissions by 29% by 2030. This is a good step for the environment in Indonesia considering the importance of laws and regulations on climate crisis and energy use. These movements cannot be carried out only in certain countries, but instead must be conducted collectively by all countries to bring about a greater impact on environmental sustainability in the world.

In terms of population growth and income inequality, although population does not have a significant influence on CO2 emissions in Java, population growth must be controlled at a reasonable rate to reduce the risk of more complex problems such as poverty, income inequality and other problems. Likewise, for income inequality, although research results show that low level of income inequality increases CO2 emissions, this issue cannot be underestimated. It has to be addressed by the government of Indonesia considering the vast territory of the country, making it very possible for inequality to occur and persist. In general, there are a lot of measures that can be taken, namely technological innovations, waste management, maintaining sustainable economic growth, creating pro-environment policies, maximizing the use of new and renewable energy, increasing public awareness and controlling population growth rates and income inequality in Indonesia in general and in Java in particular as the center of government and economic activities of Indonesia.

CONCLUSION AND SUGGESTION

This research demonstrates that, in the short term, per capita income growth brings damage to the environment. However, this relationship shifts in the long run and forms an N-shaped curve. The existence of N-shaped EKC is detected, but is insignificant. Two inflection points of the curve, at Rp 154,297,936 and 1,136,629,791, are also examined and proved the difference in results with other studies. Population growth is not proven to have a large effect on CO2 emissions, in contrast to income inequality and the SDGs which affect CO2 emissions significantly. The form of N in the EKC occurs because the reduction in CO2 emissions is temporary and the environmental improvement that is less than optimal causes the increase in the pollution level to reoccur. This condition is commonly called "technical obsolescence" or obsolescence of technical effects. In the long term, public awareness of the environment and the policies that have been established are no longer effective.

The policy implication of the study results is that optimizing economic growth is one of the requirements to preserve the environment. The most certain form or effort to restore environmental degradation and damage that has been caused is to become a prosperous country or to become a country that is financially able to restore the environment. In an effort to achieve this, a high economic growth is needed every year, but must be supported by strong institutions in order to keep development within the sustainable corridor.

Long-term policies are therefore needed to prevent technical obsolescence such as technological innovation, waste management, maintaining sustainable economic growth, creating pro-environment policies, maximizing the use of new and renewable energy, increasing public awareness as well as controlling population growth rates and income inequality. There are other factors such as environmental awareness, energy use, environmental regulations, bureaucracy and others that might be used as a reference for further research. This study has several limitations, one of which is the availability of data. The incomplete data for several local areas should be addressed by the relevant government agencies since it will lead to low data quality and doubts over data reliability.

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