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Environmental quality, economic growth and population density: A panel study in Indonesia

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ABSTRACT

Environmental quality is one of the topics that is widely discussed. The environmental quality degradation such as increasing greenhouse gases will induce climate change that will affect many sectors. This study aims to estimate the determinants of environmental quality in 33 provinces in Indonesia from 2016 to 2022. The data was generated from Ministry of Environment and Forestry and Statistics Indonesia. Many studies observe the determinant of environmental quality or its relationship with economy and population. However, the results are still varied. This study fills the gap by utilizing the Environmental Quality Index (EQI) as the proxy of environmental quality while most studies in Indonesia use CO_2. Economic growth, human development index, population density, and forest coverage are treated as independent variable. This study employs the Fixed-Effects model in estimating the data. The results revealed that the human development index positively and significantly affects the environmental quality index. Meanwhile, it is found that population density affects The Environmental Quality Index (EQI) negatively. Policymakers can construct policies in sustainable development such as building more extensive green space, restricting land use, and increasing human development to keep the environmental quality better.

1. Introduction

Climate change is an inevitable global phenomenon. Studies reported that low environmental quality indicators are from the higher concentrations of greenhouse gases for example carbon emission (CO_2) (Özgün et al., 2024). The greenhouse gases can cause climate change by trapping heat in the atmosphere and resulting in warmer temperatures (Asaka & Denham, 2023). The low environmental quality is considered a negative externality of population growth and economic activities. The United Nations reported that the world population would reach 8 billion in mid-November 2022 from 2.5 billion estimated in 1950. The increasing population induces a higher production of goods and services. The demand of the needs requires more input factors such as energy utilization. The production process not only results in goods and services but also waste. The waste can be formed as air pollution, solid waste, heat waste, and water pollution (Tietenberg & Lewis, 2018). The waste and pollution can endanger the environment including air, water, river, land, and forest. Even stated that negative externalities of low environmental quality can cause acid rain and disease (Lestari & Aisyah, 2022). Moreover, the increasing population will also increase the needs of the land area (Arshad et al 2020; Adrian, 2023). Thus, in that way, there will be a decreasing number of forest areas. The forest area is decreasing with the size of 437 million Ha from 2001 to 2021 (Adrian, 2023). The size is equal

to the increasing CO_2 as many as 174 Gt. The decreasing forest area also reduces the effectiveness of forests in preventing environmental degradation, regulating water systems, and preserving habitats for various genetic resources that are highly valuable for the advancement of science and technology. The decreasing environmental quality surely will result in the change of climate.

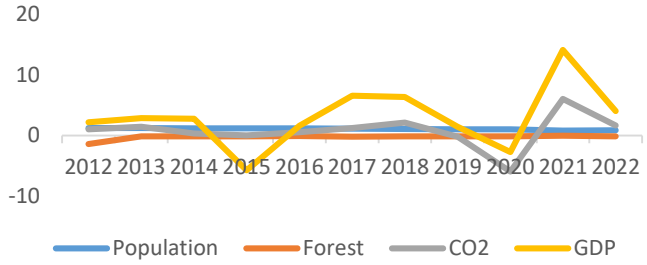

Figure 1. Population, Forest Area, CO_2 Emission and GDP in the World

Figure 1 shows the world's population, Gross Domestic Product (GDP), forest area, and Carbon Emissions (CO2) from 2012 to 2022. The population growth looks stagnant. It experienced ups and downs. The same trend for forest areas was also rather stagnant, though the trend was decreasing. The figure also shows that the increasing GDP aligns with increased CO_2 emissions. From the Figure, it can be implied that the increasing GDP is related to environmental quality which is represented by the CO_2 emissions. From Figure 1, it can be concluded that there is a relationship among population, forest area, CO_2 emissions, and GDP. The increasing population boosts the production of goods and services and increases the land use that decreases the forest area. Further, this condition will lead to environmental quality degradation that can be represented by CO_2 emissions or Environmental Quality Index (EQI).

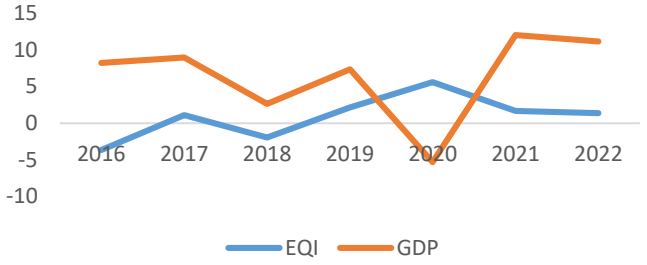

Figure 2. GDP and Environmental Quality Index in Indonesia

In Indonesia, the environmental condition is measured by the Environmental Quality Index (EQI). Figure 2 shows the growth of EQI and Gross Domestic Product (GDP) in Indonesia from 2016 to 2022. The Ministry of Environment and Forestry of Indonesia breaks down the EQI score into six ranges. A higher index implies an increase in environmental quality. The index of $90 \leq EQI \leq 100$ means the excellent quality; the index $70 \leq EQI < 90$ means a good quality of environment; the $50 \leq EQI < 70$ means the moderate quality; the the poor quality ranged $25 \leq EQI < 50$, and the very poor quality ranged $0 \leq EQI \leq 25$. The data revealed that the environmental quality in Indonesia experiences back and forth. The environmental quality was increase in 2017, 2019, and 2020, but then decreased in 2021 and 2022. The pattern is linear with the growth of GDP from 2016 to 2019. However, the environmental quality is not linear with the GDP growth in 2020 and 2021. The negative relationship between the growth of EQI and GDP in 2020 is mainly caused by the Covid-19 outbreak. The government restricted many activities at that time, which led to a drop in economic activities. The condition leads to declining economic growth. However, some reports revealed that during that time, the environmental quality improved due to the low activities. Muhammad et al (2020) revealed that in Wuhan, Italy, Spain, and USA, pollution is reduced by 30%.

This study provides empirical research from Indonesia. The estimation will observe the determinant of the environmental quality by using Environmental Quality Index (EQI) as dependent variable in Indonesia from 2016 to 2022 while most studies in Indonesia have used CO_2 as the proxy of environmental quality. Furthermore, many studies utilized economic growth, a number of industrial

sectors, population, and poverty as independent variables. This study attempts to fill the gap by utilizing other variables such as Human Development Index (HDI), population density, and forest area on environmental quality in Indonesia from 2016 to 2022. The results contribute to the addition to the literature regarding the determinant of environmental quality especially in Indonesia.

2. Literature Review

Environmental quality can be measured by CO_2 emissions or CO_2 emissions per capita (Aller et al., 2021). Furthermore, global trends index of pollution, CO_2 emission, and environmental protection's general government expenditure can also be the proxy of environmental quality indicators (Chen et al., 2019; Cahyadin et al., 2021). The Ministry of Environment and Forestry of Indonesia constructed an Index to measure the environmental quality, namely the Environmental Quality Index (EQI). The Environmental Quality Index in Indonesia measure three dimensions which are air quality, water quality, sea water quality, and forest cover. Research regarding the determinant of environmental quality has been conducted in many countries by using different approaches and methods. A number of variables are also tested to determine the relationship with environmental quality. Environmental Kuznet Curve (EKC) theory explains the inverted U shape between economic growth and environmental degradation. There are three stages in the relationship between economy and environmental quality (Zulfikar et al., 2021). The first stage is pre-industrial. In this stage, a country develops its economy and is followed by the environmental degradation. It is because the early stage of economic development usually requires cost efficiency which does not consider the environmental effect of the process. The second stage is industrial economy phase and the third phase is post-industrial economy. The second stage shows the economic transformation which leads to the increasing income level that leads to the ability to pay the environmental damage. Finally, at the third stage, increasing economic activities will decrease environmental degradation.

Setiawan & Anwar (2022) stated that it was first introduced by Grossman & Krueger (1995) by estimating the relationship between GDP per capita and environment. Studies on EKC theory results are inconsistent. Wafa (2024) estimated the relation between GRDP and Environmental Quality Index (EQI) in Indonesia from 2016 to 2022. The results revealed that GRDP affect EQI positively. It implies that the increasing economic activities that represent by GRDP will make the environmental quality better. However, different results are found by Finanda & Gunarto (2022). The increasing Gross Regional Domestic Product (GRDP) will decline the environmental quality in Sumatra Island, Indonesia from 2011 to 2019. Research by Susilowati et al (2023) utilized CO_2 as the proxy of environmental quality. The results revealed that economic growth negatively affect CO_2 in the long term in 10 ASEAN Countries from 2001 – 2020. Rahayuningrum (2024) revealed that EKC hypothesis cannot be found in Indonesia. The study estimated the relationship between Gross Domestic Product (GDP) and CO2 emissions in Indonesia from 1990 to 2019 by using VECM method. The result highlighted that GDP has no significant effect on CO_2 emissions.

Human Development Index (HDI) is often treated as the determinant of environmental quality. HDI is the proxy of human resources quality (Nguyen, 2022; Widiastuti et al., 2022). Research by Alsharef et al (2024) estimated the relationship between environmental quality and human development index (HDI) in three provinces in Libya from 2013 to 2021. In Libya, the lower value of the environmental quality index means the better the quality. The results revealed that there is a negative relationship which implies that the increasing HDI will decrease the environmental damage. Study by Mrabet & Alsamara (2017) in 16 MENA countries from 1990 – 2016 found that the increase HDI will make the environmental quality better. Furthermore, research by Opoku et al (2022) that covers all OECD countries except Chile, Colombia, Iceland and Luxembourg from 1996 to 2016 found that an increase in HDI, education, and human capital lead to the decreasing ecological footprint. Human development will reduce the CO_2 and the other greenhouse gases emissions.

Population is also considered as the determinant of environmental quality. Research by (Borck & Schrauth, 2021) tried to explore the relationship between air pollution and population density in Germany from 2005 – 2012. The results revealed that the increasing population density will increase NO_2 and PM_{10} which are the proxy of air quality. Another research by Rahman (2020) found that in India from 1971 to 2011, population density will increase CO_2 emission which is one of the proxies of environmental quality. In Indonesia, study by Wafiq & Suryanto (2021) found that there is a negative relationship between population density and environmental quality index (EQI) in Indonesia from 2010 to 2016. It means that the increasing population density will decrease the environmental

quality. The results also align with a study by Aida et al (2022) which revealed that the increase of population density will decrease the Environmental Quality Index in Java Island from 2010 to 2019.

Another factor that affects environmental quality is forest area or forest coverage. Forest can provide a good quality of drinking water. Forest also can affect the environmental quality, in this case is water quality in many ways such as landslides or wildfire that can increase the concentration of sediment (Pike et al, 2010). A study by An et al (2022) that observes The Three Gorges Eco-Economic Corridor, as an ecological barrier area in the middle and upper reaches of the Yangtze River, China found that in the higher urbanization area the forest cover was low and resulted in a poor environmental quality. The results show that the number of districts that have bad and poor environmental quality is increasing from 3 to 8. It implies that the increasing activities generated from urbanization will lower the forest cover and degrade the environment. The relationship between forest cover and environmental quality shown by result from Qiu et al (2023). The study highlighted that the higher forest cover rates will improve water quality. Research by Raihan et al (2023) revealed that there is a negative relationship between forest cover and CO_2. An increase in forest cover will drop the CO_2 emissions as one of the proxies of environmental quality. Arif & Hardimanto (2023) also found that the increasing deforestation will degrade the environmental quality in Indonesia from 2015 to 2020.

3. Method

This study utilizes panel data that covers 33 provinces in Indonesia from 2016 to 2022. The data is secondary data which was collected from Ministry of Environment and Forestry and Statistics Indonesia. Gujarati (2004) explained that panel data is a combination of time series and cross section data. EQI or Environmental Quality Index is treated as a dependent variable, while GRDP growth (lngrdp), Human Development Index (HDI), population density (lnden), and forest coverage (lnfor), are treated as independent variables. Table 1 shows the variable specification of this study and the definition of each variables used in this study.

Table 1. Definition of Variables

No	Variable	Definition	Source
1.	EQI	EQI is the Environmental Quality Index which measure the environmental quality in a certain area and time. The value of the index is a composite value of Water Quality Index, Air Quality Index, Land Quality Index and Sea Water Quality Index.	Ministry of Environment and Forestry
2.	lngrdp	The growth of Gross Regional Domestic Product (GRDP) at current market price (billion rupiahs)	Statistics Indonesia
3.	HDI	Human Development Index (HDI), which is an index that explains how the population is able to access the development in order to increase their income, health and education.	Statistics Indonesia
4.	lnden	The population density per km^2	Statistics Indonesia
5.	lnfor	Forest coverage. According to Law number 41/1999, forest coverage is vegetation with a certain composition and density that cover the forest area. In this way, the forest function is developed such as microclimate, water, and habitats for animals as forest ecosystems.	Ministry of Environment and Forestry

Source: BPS and Ministry of Environment and Forestry

Baltagi (2008) explained that there are some advantages in using panel data: (1) Panel data able to control individual heterogeneity, (2) Panel data provides more informative data, more variability, less collinearity, more degrees of freedom, and is more efficient, (3) Panel data is better in observing the

dynamics of adjustment, (4) Panel data is better in identifying and measuring the effects that the cross-section and time series data cannot do, and (5) Panel data models are able to test more complicated behavioral models that cross-section and time series data cannot do. In addition, panel data regression offers several key advantages over traditional cross-sectional or time-series analyses. According to Vomberg & Wies (2021), panel data allows researchers to better control for omitted variable bias and unobserved heterogeneity by tracking individual entities over time, thus improving the accuracy of causal inferences. Similarly, Gil-García & Puron-Cid (2013) highlight that panel data techniques, particularly fixed and random effects models, provide more robust estimations by controlling for time-invariant characteristics that might otherwise confound results. Ibrahim & Arundina (2022) point out that panel data increases variability, reduces multicollinearity, and improves model efficiency, making it particularly useful in financial research. Baltagi (2008) adds that panel data allows for the study of dynamic relationships, capturing both cross-sectional and time-series variations while mitigating issues of aggregation bias. These combined benefits make panel data regression a valuable tool for analyzing complex economic and social phenomena.

Fixed Effects (FE) and Random Effects (RE) are two models that are commonly used in estimating panel regression. Baltagi (2008) stated that the random effects model can be employed when having a randomly large population of N or the cross section. Meanwhile, the fixed effects model focuses on a specific set of N. For example, 10 ASEAN Countries. The Hausman test needs to be performed in order to choose the most appropriate model between Random effects and Fixed Effects. If the null hypothesis is rejected or the p-value of Chi-squared is < 5% critical value, then the most appropriate model is FEM (Hausman, 1978). The equation for panel data as follows:

$$EQI = (\beta_0 + \lambda_i) + \beta_1 lngrdp_{it} + \beta_2 HDI_{it} - \beta_3 lnden_{it} + \beta_4 lnfor_{it} + \mu_{it} \quad (1)$$

Where *EQI* is the Environmental Quality Index; *lngrdp* is the growth of Gross Regional Domestic Product at current prices (million rupiahs) of each province in Indonesia; *HDI* is human development index; *lnden* is population density per Km^2; *lnfor* is forest coverage β1 - β4 are the regression coefficients; β0 is constanta and i and t indicate cross-section and time series, respectively.

4. Results and Discussion

Table 2 shows there are two common models in estimating panel data using static panel approach. The models are Random Effects (RE) and Fixed Effects (FE). Table 2 shows the results of RE and FE estimations. The effect of GRDP growth at current prices vary between RE and FE results. The FE results show that the coefficient of *lngrdp* is positive but statistically not significant. Meanwhile, the RE estimation results showed that the coefficient of *lngrdp* is negative and significant at 5% level. The *hdi* shows positive and significant at 1% level both from the RE and FE results. Population density *(lnden)* has negative coefficient both in RE and FE estimation results but at different critical value which are at 1% and 10% respectively. Furthermore, forest coverage has positive coefficient both from RE and FE estimation results.

Table 2. Random Effect and Fixed Effect Estimation Result

Variables	RE Coefficient	FE Coefficient
lngrdp	-1.185**	0.639
	(-2.12)	(0.64)
HDI	0.837***	1.861***
	(5.86)	(8.10)
lnden	-4.157***	-13.048*
	(-6.32)	(-1.67)
lnforest	1.115***	0.632
	(2.97)	(1.60)
Cons	44.856***	-15.622
	(2.97)	(-0.39)
Obs	231	231

Source: data processed

To choose between Fixed Effect (FE) and Random Effect (RE), the Hausman Test is performed. The probability value of Chi-squared in the Hausman Test is 0.000; which means that the Fixed-Effect model is preferred. Furthermore, this study also tested the existence of multicollinearity and

heteroscedasticity. The multicollinearity test uses the Mean VIF Value. If the value is greater than 10, it means that the multicollinearity exists. The mean VIF value is 3.20. Thus, multicollinearity does not exist. Meanwhile, the heteroskedasticity test revealed the prob value of 0.000 which indicates that the heteroskedasticity problem exists.

Table 3. Fixed Effect Estimation Result

Variable	Coefficient
lngrdp	0.639
	(0.63)
HDI	1.861***
	(5.74)
lnden	-13.048*
	(-1.85)
lnforest	0.632
	(1.41)
Cons	-15.622
	(-0.45)
Obs	231

Source: data processed

This study uses STATA 17 as a tool in estimating the data. STATA provides "robust" command to deal with heteroskedasticity problem. Table 3 shows the estimation results after the "robust" command is executed. The results showed that there is a positive relationship between Gross Regional Domestic Product (GRDP) growth at current market price (*lngrdp*) and environmental quality index (EQI). However, the effect is not significant. The results in line with research by Rahayuningrum (2024) which found that there is no significant effect of GRDP on EQI. However, the positive relationship from the estimation results can confirms that the Environmental Kuznets Curve is at the third stage. It means that the increasing income by economic activities will increase the Environmental Quality Index which means that the environmental degradation is reducing (Tietenberg & Lewis, 2018). The results are aligned with Wafa (2024) that found the positive relationship between GRDP and EQI in 34 provinces in Indonesia from 2016 to 2022. The increasing GRDP will increase the Environmental Quality Index. It implies that the ability to pay the environmental losses is increasing as the income rises. Furthermore, this condition is a good progress since the Indonesian government, through Law No. 32 of 2009, mandates that every business to be conducted must include environmental documents such as AMDAL or Environmental Impact Assessment. The environmental documents are treated as an instrument to control business activities to prevent pollution and hazardous substances that could harm the environment. Thus, when an upcoming business has the potential to degrade the environment, the government will not issue the permit.

The estimation results (Table 3) showed that the Human Development Index (HDI) affected the Environmental Quality Index (EQI) in 33 Provinces in Indonesia from 2016 to 2022 positively at 5% critical value. The 1 unit increase in HDI will increase EQI by 1.861 units. HDI is an indicator of human life quality that covers the aspect of education, health, and economy (Muta, 2024; Pereira & Mota, 2016). The higher HDI means the better quality of education, health, and economy. The results support previous results by Shahabadi & Heidarian (2024) which revealed that the better quality of education will induce conscious work to gain a clean and healthy environment. The increasing quality of life that is pictured by HDI is a signal that there is an increase in the general knowledge and awareness regarding the environment. Thus, the improved quality of a human being in a certain area will make the environmental quality better.

Population density shows a negative impact on environmental quality at 5% critical value. It means that the 1% growth in population density will lead to a decrease in environmental quality by 13.048 points. The result is aligned with research by Dinilhaq & Azhar (2024) revealed that the increasing population density will decrease the environmental quality. The increasing population density is a proxy for population growth and urbanization. The condition leads to the increasing demand of goods and services. For example, the expanding civilization requires resources such as electricity to make a better life. Meanwhile, in Indonesia, most electricity generation or power plants use fossil fuels such as coal (Hasan, et al 2012). Meanwhile, the emissions from coal power plants are 12 times greater than geothermal as renewable energy (Alhamid et al., 2016).

The forest cover as an independent variable shows positive but not significant. However, the positive relationship implies that the increasing forest cover will make the EQI higher, which means that the environmental quality is increasing. As described above, according to Law number 41/1999, forest coverage is an area covered with a certain composition of vegetation which results in forest function such as microclimate, water, and habitats for animals as a forest ecosystem. Research by Fiquepron et al (2013) found that forest cover has a positive impact on raw water. The existence of forest cover will make a better quality of raw water. Furthermore, the research also highlights the economic effect of forest cover which has the potential to drop water prices. The better quality of raw water represents the quality of the environment. Additionally, forests are also able to reduce CO_2 emissions as one of the proxies of environmental quality (Waheed et al., 2018). The insignificant effect of forest coverage on EQI may caused by the fact that the forest area is a quantity indicator, not a quality indicator (Wang, 2003).

5. Conclusion

Research regarding the determinant of environmental quality has been widely conducted. The discussion is not only limited to nature science approach but also social science including economics. This study estimates the effect of economic growth (lngrdp), human development index (hdi), population density (lnden), and forest cover (lnforest) on Environmental Quality Index (EQI) in 33 provinces in Indonesia from 2016 to 2022. The data was estimated by using the panel static approach in Fixed Effects model. The results revealed that HDI affects EQI positively. It means that increasing human resources quality will make environmental quality better. Furthermore, population density affects EQI negatively. It implies that the increasing population density will expand industrial activities due to the increasing demand for goods and services. Industrial activities will escalate the fossil fuel utilization and waste as pollution which can endanger the environment. Thus, the higher population density will decrease environmental quality. Further, results revealed a positive relationship between forest coverage and the environmental quality index in Indonesia. The forest's existence will help the quality of raw water through its streams and also as a provider to reduce CO2 emissions as one of the greenhouse gases that can decrease the environmental quality.

It can be inferred from the results that several policies can be constructed to increase environmental quality. Policies that equalize economic growth and sustainability should be prioritised. The government can increase the budget for the environment to fund sustainable activities and environmentally-friendly programmes. As the number of populations increases, local governments can build public areas that contain green open space. Although it is not likely a forest, the trees and ecosystem in the green open space will be able to help to increase environmental quality. The green space will help to reduce the negative effects of the pollution and waste produced by human activities. The quality of human resources also needs to be enhanced through formal and informal education to increase their knowledge and awareness regarding sustainable development. Further, proper forest management can be performed to keep the water and air quality. Moreover, the government also can tighten the policies regarding land use to avoid extensive utilization that leads to decreasing environmental quality.

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