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Article

Economic Growth, Population Density, and Human Development: Key Drivers of Environmental Quality in Indonesia

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Abstract: In an effort to understand the interactions between economic growth, population density, the Human Development Index (HDI), and the Environmental Quality Index (EQI) in Indonesia, this study adopts a quantitative approach utilizing panel data encompassing 34 provinces during the period from 2020 to 2022. This analysis implements fixed effects models in panel data regression to isolate the impact of these variables on environmental quality. Results indicate that neither economic growth nor population density significantly affect the EQI, while an increase in HDI significantly contributes to environmental improvement, emphasizing the importance of factors such as education, health, and living standards. Furthermore, the cross-section fixed effects analysis reveals significant provincial-specific factors influencing the EQI, which macroeconomic and demographic variables cannot fully explain. Variability among provinces shows that some have a strong positive effect on the EQI, whereas others have a negative impact, highlighting the need for regionally tailored policies to enhance effectiveness in environmental conservation efforts. These findings inform policymakers about the importance of focusing on human development as a key element in strategies to improve environmental quality in Indonesia. The implications suggest that sustainable development strategies must integrate aspects of human development with comprehensive environmental policies, creating synergies that support environmental preservation. This study makes a significant contribution to the literature by providing insights into effective ways that Indonesia can adopt to address current and future environmental challenges.

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1. Introduction

The relationship between economic growth, population density, Human Development Index (HDI), and Environmental Quality Index (EQI) is a complex and multidimensional topic that has been extensively studied across various countries, including Indonesia. Numerous studies have explored these intricate interactions and the dynamics involved. One such study by Wafiq & Suryanto (2021) focused on Indonesia with the aim of determining the impact of economic growth and population density on the Environmental Quality Index. Their findings provide valuable insights into how these factors interact and influence environmental quality.

Oktavilia et al. (2018) explored the relationship between environmental degradation, poverty, human quality, population density, and global trade on environmental quality, offering a broader perspective on the determinants involved. Additionally, a study by

Esther (2023) highlighted the positive effects of HDI on environmental quality, emphasizing the importance of education and lifestyle in shaping environmentally friendly behavior. Rahmawati (2024), who demonstrated a significant positive influence of HDI on EQI in Indonesia, supports these findings. In his research in Ethiopia, Abate (2024) discovered an inverted N-shaped relationship between economic growth and environmental quality, indicating a threshold at which GDP per capita begins to contribute positively to environmental quality. This nonlinear relationship highlights the complexity of economic growth's impact on environmental outcomes. Harahap & Adry (2020) studied the determinants of HDI in Indonesia, highlighting the significant effects of energy consumption, environmental quality, and economic growth on HDI. Their comprehensive analysis provides important insights into the intricate relationships among these variables.

Li et al. (2015) explored the relationship between financial development, environmental quality, and economic growth, emphasizing how improvements in environmental quality can strengthen the impact of financial development on economic growth. Their research indicates a reinforcing cycle where enhanced environmental quality can drive economic growth. Yıldırım (2024) revealed a U-shaped relationship between environmental quality and economic development, showing that environmental quality may initially deteriorate before improving as economic development progresses. This nonlinear pattern highlights the complex nature of the relationship between economic growth and environmental outcomes. Research by Ong et al. (2021) in Malaysia provided important insights into the link between economic growth and environmental performance. They identified and analyzed factors influencing this relationship, offering additional guidance in understanding the dynamics occurring in Indonesia. Samimi et al. (2010) provided evidence from several developing countries, demonstrating the connection between the Environmental Performance Index and economic growth, and offering additional insights pertinent to the Indonesian context.

Recent research by Bose et al. (2024) provided evidence from SAARC countries about improved environmental performance. This study highlights the importance of regional cooperation in enhancing environmental performance and shows how countries can learn from each other to achieve better environmental goals. Shanty et al. (2018) investigated the relationship between environmental degradation, poverty, and human quality in Indonesia, providing additional evidence of the negative impact of environmental degradation on the quality of life, enhancing understanding of how social and environmental factors interact. Research by Li & Xu (2021) research provided significant insights into the relationship between human development and environmental quality in China, demonstrating a close link between improvements in environmental quality and advancements in human development. Uddin et al. (2021) showed how improving the quality of human capital can lessen the negative effects of economic growth on the environment. They did this by re-examining the Environmental Kuznets Curve (EKC) hypothesis and pointing out how important it is to build up human capital.

Research by Fakher & Murshed (2023) examined whether economic and financial expansion allows for environmental sustainability. Using a new composite index and PSTR analysis, this study presents new insights into how economic and financial growth can play a role in environmental sustainability. Overall, these studies collectively contribute to a better understanding of how economic growth, population density, HDI, and EQI intersect and affect each other. By synthesizing these findings, policymakers and stakeholders can gain valuable insights into formulating strategies that promote sustainable development while preserving environmental quality[1], [2], [3], [4], [5].

2. Materials and Methods

2.1. Literature Review

Several studies have illustrated the diverse impacts of economic growth, population density, and the Human Development Index (HDI) on the Environmental Quality Index (EQI) in Indonesia. According to Yani et al. (2023), economic growth exhibits a significant negative effect on environmental quality in Indonesia. Economic activities like industrial operations and population mobility, which boost the Gross Regional Domestic Product (GRDP) but concurrently degrade environmental standards due to vehicle and waste pollution, are responsible for this outcome.

Further, research by Aulia et al. (2024) shows that human development positively and significantly impacts environmental quality, suggesting that higher levels of education and increased public awareness may foster more innovative solutions to environmental challenges. The population density has both positive and negative impacts on the environmental quality index, challenging the growth limits theory, which posits that an increase in population quantity exacerbates pollution and diminishes environmental quality [6], [7]. Over time, however, there appears to be a positive impact on improving living environments, albeit not significantly enhancing the environmental quality. Population growth and heightened environmental awareness are responsible for this.

According to Tesalonika & Sutjipto (2023), the Human Development Index significantly enhances the Environmental Quality Index across 34 provinces in Indonesia, with human development investments positively influencing circular economic development through enhanced community skills and knowledge, facilitating the discovery of alternative solutions for environmental preservation. Anastasya & Suwandana (2022) note that economic activities characterized by economic growth and per capita GRDP lead to decreased air quality in South Sumatra Province. Economic operations such as industry and mining inevitably produce residues or waste that degrade the quality. Additionally, human activities related to economic participation, like commuting, contribute to motor vehicle emissions, further reducing air quality in the province. These findings align with the Environmental Kuznets Curve hypothesis and previous research, which observes that rapid population growth accompanied by brisk economic activity intensifies environmental degradation. This necessitates government policies on environmental management regulations, such as local ordinances or mayoral regulations governing waste disposal, mining permits, and reducing plastic bag use.

Luhung & Yuniasih (2023) also record the fluctuating nature of Indonesia's EQI, with certain indices such as water quality and land cover showing moderate and stagnant ratings, thereby emphasizing the need for sustainable development policies to mitigate environmental impacts. Overall, these findings indicate that while economic and demographic factors often contribute negatively to environmental quality, integrating human development and sustainable practices can mitigate these impacts and enhance environmental quality in Indonesia.

2.2. Data and Analysis Techniques

This quantitative study utilizes panel data covering 34 provinces in Indonesia from 2020 to 2022, with economic growth, population density and the Human Development Index as independent variables, and the Environmental Quality Index as the dependent variable. Data for this research was sourced from various sites, including the Central Bureau of Statistics (BPS) and the Ministry of Environment and Forestry.

Panel data regression analysis was employed to ascertain the effects of the independent variables (economic growth, population density, and HDI) on the dependent variable (EQI). The models used include fixed effects and random effects. The panel regression equation employed is as follows:

$$〖EQI〗_it=\alpha+\beta_1 〖PE〗_it+\beta_2 〖KP〗_it+\beta_3 〖HDI〗_it+\mu_i+\epsilon_it$$

Where EQIit represents the Environmental Quality Index in province i at time t. α is the constant. β_1, β_2, β_3 are the regression coefficients for the independent variables. PE denotes Economic Growth, KP denotes Population Density and HDI stands for Human Development Index. μ_i represents the province-specific effects and ϵ_it is the error term.

All statistical analyses were conducted using Eviews software with a significance level set at $p < 0.05$. The panel regression models used include the Fixed Effects Model, which controls for unobserved variables that could be correlated with both the independent and dependent variables, and the Random Effects Model, which is used to determine if variations across provinces can be considered random and uncorrelated with the independent variables. To determine the appropriate model for the panel regression, the Chow Test is employed to decide between the Common Effects Model and the Fixed Effects Model, while the Hausman Test is utilized to ascertain the more suitable model between Fixed Effects and Random Effects.

3. Results

The Fixed Effect Model (FEM) is employed to control for variables that are constant over time but may vary between observational units (in this case, between provinces). FEM helps to isolate the impact of variables that change over time (such as population density, economic growth, and the Human Development Index) on the Environmental Quality Index. Based on the outcomes of panel model testing, two principal tests have been conducted to determine the most suitable model for this panel data analysis: The Chow Test and the Hausman Test. The results of the Chow Test show a statistical value of 276.10 with degree of freedom (d.f.) of 33 and a probability (Prob.) of 0.00. These results indicate that the Fixed Effects Model (FEM) is more appropriate compared to the pooled data model (common effects model) due to the highly significant probability value.

Table 1 Panel Model Selection

Test	Statistic Value	d.f.	Prob.	Result
Chow	276.10	33	0.00	FEM
Hausman	29.69	3	0.00	FEM

Additionally, the Hausman Test was conducted to determine whether the Fixed Effects Model (FEM) or the Random Effects Model (REM) is more suitable for this data set. The results of the Hausman Test revealed a statistic value of 29.69 with 3 degrees of freedom (d.f.) and a probability (Prob.) of 0.00. These results indicate a high level of significance, suggesting that the Fixed Effects Model (FEM) is more appropriate compared to the Random Effects Model (REM) for this analysis. Consequently, these two tests consistently show that the Fixed Effects Model (FEM) is the most appropriate model to use in this study.

The results from the regression analysis using the Fixed Effects Model (FEM) demonstrate the relationships between economic growth (PE), population density (KP), and Human Development Index (HDI) on the Environmental Quality Index (EQI). The constant coefficient (C) yielded a t-statistic of -63.62 with a probability (Prob.) of 0.04, indicating significance at the 5% level. The variable representing economic growth (PE) recorded a t-statistic of 0.03 with a probability of 0.44, suggesting that economic growth does not have a significant influence on the EQI within this model.

Table 2 Fixed Effect Model (FEM)

Variable	t-stat	Prob
C	-63.62	0.04
PE	0.03	0.44
KP	-0.0007	0.91
IPM	1.88	0.00

R-Squared	0.97
F-Stat	57.05
Prob-F	0.00

Population density (KP) also did not exhibit a significant influence on the Environmental Quality Index (EQI), with a t-statistic of -0.0007 and a probability of 0.91. Conversely, the Human Development Index (HDI) showed a significant effect on the EQI, as evidenced by a t-statistic of 1.88 and a probability of 0.00, significant at the 1% level. The R-squared value of this model is 0.97, indicating that 97% of the variation in the EQI can be explained by the independent variables within the model. The F-statistic value of 57.05 with a probability (Prob-F) of 0.00 indicates that the model is statistically significant at the 1% level. Overall, these results demonstrate that among the three independent variables tested, only HDI has a significant impact on EQI, whereas PE (Economic Growth) and KP (Population Density) do not show significant effects. This model demonstrates excellent capability in explaining the variations in EQI, as indicated by the high R-squared value.

Table 3 Cross Section Fixed Effect

No	Province	Effect	No	Province	Effect
1	Aceh	2.03	18	Nusa Tenggara Barat	1.09
2	*Sumatera Utara*	*-3.30*	19	Nusa Tenggara Timur	11.56
3	*Sumatera Barat*	*-2.53*	20	Kalimantan Barat	5.58
4	*Riau*	*-4.48*	21	Kalimantan Tengah	1.73
5	*Jambi*	*-2.61*	*22*	*Kalimantan Selatan*	*-3.77*
6	*Sumatera Selatan*	*-0.86*	*23*	*Kalimantan Timur*	*-4.74*
7	*Bengkulu*	*-3.00*	24	Kalimantan Utara	9.31
8	*Lampung*	*-1.62*	*25*	*Sulawesi Utara*	*-3.38*
9	*Bangka Belitung*	*-0.99*	26	Sulawesi Tengah	8.90
10	*Kep. Riau*	*-9.98*	*27*	*Sulawesi Selatan*	*-1.38*
11	*DKI Jakarta*	*-24.95*	28	Sulawesi Tenggara	3.57
12	*Jawa Barat*	*-10.22*	29	Gorontalo	9.87
13	*Jawa Tengah*	*-4.21*	30	Sulawesi Barat	10.16
14	*Yogyakarta*	*-20.09*	31	Maluku	6.57
15	*Jawa Timur*	*-5.25*	32	Maluku Utara	9.55
16	*Banten*	*-13.49*	33	Papua Barat	21.08
17	*Bali*	*-8.73*	34	Papua	28.58

The Cross Section Fixed Effect values generated demonstrate specific provincial differences in the dependent variable that are not explained by the independent variables. These values may reflect fixed factors or unique characteristics of each province that influence the quality of the environment. There are 14 provinces exhibiting positive Cross Section Fixed Effect values and 20 provinces with negative values. The provinces with the highest positive Cross Section Fixed Effect values are Papua and Papua Barat, while DKI Jakarta and Yogyakarta are the provinces with the largest negative values.

4. Discussion

Regression analysis using the Fixed Effects Model (FEM) provides key insights into the relationships between economic growth (PE), population density (KP), and The Human Development Index (HDI) on the Environmental Quality Index (EQI). Each independent variable displays varying impacts on environmental quality, which can be contextualized with findings from previous studies. While the independent variables are important factors generally influencing environmental quality in Indonesia, the fixed

effects values indicate that there are other province-specific factors that also significantly influence outcomes.

The analysis reveals that economic growth (PE) does not have a significant impact on the EQI. This finding suggests that economic growth does not directly affect environmental quality in the context of this panel data. This result aligns with the study by Li et al. (2015), which stated that while improvements in environmental quality can strengthen the effects of financial development on economic growth, they do not always directly impact environmental quality. Furthermore, this finding is consistent with research by Abate (2024) in Ethiopia, which identified an inverted N-shaped nonlinear relationship between economic growth and environmental quality, indicating that positive impacts of economic growth on environmental quality only occur after reaching a certain income level.

Population density (KP) also does not show a significant effect on the EQI. This outcome suggests that variations in population density did not directly impact environmental quality in Indonesia during the study period. Oktavilia et al. (2018) revealed that population density could interact with other variables such as environmental degradation and poverty, indicating that the impact of population density on environmental quality may be more complex and not directly explicable by this model. Additionally, Samimi, Erami, and Mehnatfar (2010) noted that the impact of population density on environmental quality can vary depending on different economic and social contexts.

The Human Development Index (HDI) demonstrates a significant influence on the EQI, indicating that improvements in HDI play a crucial role in enhancing environmental quality. This finding is consistent with research by Esther (2023) and Rahmawati (2024), which showed that HDI, encompassing aspects of education, health, and living standards, is vital in fostering environmentally friendly behavior and enhancing environmental awareness. This result is also supported by the study by Li & Xu (2021) in China, which showed that improvements in environmental quality could be closely linked to advancements in human development.

Provinces with positive "Effect" values indicate characteristics within those provinces that tend to enhance environmental quality (independent of the variables studied). Conversely, provinces with negative "Effect" values may face structural challenges or possess specific characteristics that tend to reduce environmental quality. This analysis underscores the importance of understanding and addressing unique structural factors and policies for each province to more effectively enhance environmental quality. Provinces with positive Fixed Effects need to maintain and even enhance policies and practices that have been successful. In contrast, provinces with negative Fixed Effects require more focused interventions, such as identifying the root causes of unique environmental issues and designing more targeted policies.

5. Conclusion

Overall, the analysis results indicate that of the three variables tested, only the Human Development Index (HDI) has a significant influence on the Environmental Quality Index (EQI). This suggests that improving HDI through improved education, health, and living standards should be the primary focus to enhance environmental quality in Indonesia. Economic growth and population density do not show significant effects in this model; however, it is still important to consider their interactions with other factors in efforts to achieve sustainable development. These findings provide guidance for policymakers to prioritize human development as a central strategy for maintaining and enhancing environmental quality.

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