



Determinants of Environmental Quality in Indonesia: The Role of Democracy, Socio-Economics, and Financial Development

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ABSTRACT

Sustainable development requires a good quality of life for all. Therefore, we investigated the short- and long-term dynamics of the Environmental Quality Index (EQI) across 34 provinces in Indonesia from 2015 to 2023 using a Panel Error Correction Model. The explanatory variables included the democracy index, population density, education level, wages, poverty, foreign investment, domestic investment, and Gross Regional Domestic Product (GRDP). In the short term, GRDP reduced the EQI by 0.32 units, while the others did not show a significant impact. In the long term, democracy increased the EQI by 0.13 units, education level by 12.29 units, and poverty by 0.01 units, while GRDP and population density reduced it by 0.09 units and 0.16 units, respectively. Further analysis revealed that GRDP derived from the mining sector reduced the EQI, whereas service sectors such as education and health contributed to its improvement. Based on these findings, local governments should integrate environmental protection directly into their development agendas by implementing rigorous environmental impact assessments, expanding green infrastructure, and providing targeted incentives for the development of low-carbon industries.

1. INTRODUCTION

Indonesia is increasingly focusing on the quality of its living environment, which is closely linked to economic development, urbanization, and social change (Aryani et al. 2025, Lukman et al. 2025, Wahyuningrum et al. 2025). The Ministry of Environment and Forestry (KLHK) publishes the Environmental Quality Index (EQI) as a comprehensive indicator of the condition of the air, water, and soil. This index is widely used to assess the effectiveness of construction and development projects (KLHK 2022). Previous studies have affirmed that democracy exerts a positive effect on environmental performance, although its effects tend to be indirect (Islam et al. 2023, Persakis et al. 2024, Povitkina & Jagers 2022). The effectiveness of democracy in advancing environmental quality depends heavily on bureaucratic capacity, the strength of formal institutions, market dynamics, and pressure from interest groups and civil society (Fredriksson & Wollscheid 2015).

Democratic maturity is generally associated with greater transparency and accountability in governance, which can contribute to improved environmental quality. However, in the Indonesian context, the relationship between democracy and environmental quality is inconsistent because improvements in democratic practices do not always result in better ecological outcomes. This challenge is compounded by rapid urbanization, particularly in densely populated areas where environmental degradation is often intensified (Fukuyama et al. 2025). As illustrated in Fig. 1, DKI Jakarta, the nation's economic and political hub, has the lowest EQI (highlighted in red). This suggests severe environmental pressure caused by concentrated economic activity, high population density, and rapid urban expansion

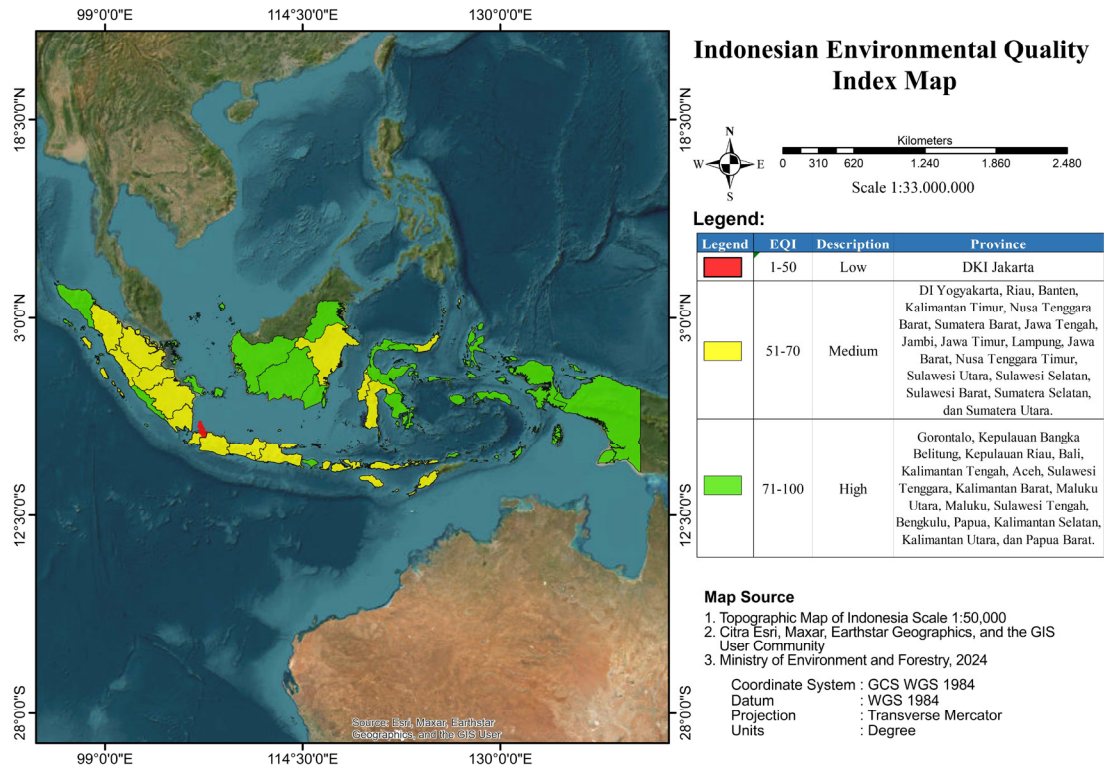


Fig. 1: Indonesian Environmental Quality Index Map.

Limited access to safe water persists across large regions of the world and is aggravated by organic, inorganic, and biological contamination of surface sources. In this context, turbidity is an operational indicator of sanitary risk because of its association with colloids and particles that transport contaminants (Ogunshina et al. 2023). Conventional clarification using mineral coagulants, such as aluminum sulfate, is effective; however, it has disadvantages related to cost, availability, and chemical residues, motivating the search for more sustainable alternatives (Don et al. 2025). Education is another crucial factor that affects environmental quality. Higher levels of education enhance public awareness and understanding of ecological issues (Barnes et al. 2025, Sumy et al. 2023). Hu et al. (2025) and Luo et al. (2025) similarly demonstrate that education has a positive correlation with pro-environmental behavior. Furthermore, Wijethunga et al. (2025) and Rachid et al. (2025) discovered that financial development affects environmental quality. Investment, often regarded as a catalyst for economic growth, exerts pressure on the environment (Bui Minh et al. 2023). Domestic investment is generally concentrated in the agricultural sector, whereas foreign direct investment (FDI) is typically directed toward the industrial sector, which can increase carbon emissions and pollution (Song et al. 2019). At the regional level, the Gross Regional Domestic Product

(GRDP) reflects the scale of economic activity, which often correlates with rising investment flows. Both factors affect the EQI, as economic growth not aligned with sustainability principles and supported by effective government oversight tends to exacerbate environmental degradation (Povitkina & Jagers 2022).

Socio-economic factors also play an important role in determining environmental quality (Pastore & de Santoli 2025). Ghosh et al. (2023) analysed this in the BRICS countries, Acheampong et al. (2022) in Sub-Saharan Africa, and Smith et al. (2024) in Indonesia. Furthermore, wages and poverty, two widely debated dimensions, have been shown to affect environmental sustainability (Arranz & García-Serrano 2025, Shah et al. 2023, Wang et al. 2023, Zhang & Zhao 2022). Conversely, higher income can lead to increased consumption of energy and materials, thereby exerting additional pressure on the environment (Afridi et al. 2019). However, several of the above studies still separate the analysis of democracy from socio-economic dimensions, thereby ignoring the potential for simultaneous correlations between democracy, given that the system in Indonesia holds regional head elections every five years. Furthermore, few studies have integrated these two variables at the regional level, particularly across Indonesia's 34 provinces, resulting in a partial explanation of variations in the EQI, which is

the official measure used by the Indonesian government to assess national environmental conditions, and failing to capture the complexity of determinants of environmental quality between regions.

Based on this framework, this study investigates how various socioeconomic, financial development, and democracy factors affect environmental quality across 34 Indonesian provinces. The findings are expected to provide valuable insights for regional leaders in formulating effective and context-specific environmental policies while also considering the constraints of their ten-year or two-term office tenure. We hypothesized that the democracy index, education level, and poverty would positively affect the EQI. In contrast, population density, wages, investment, and GRDP are expected to negatively affect Indonesia's EQI.

2. MATERIALS AND METHODS

2.1. Estimation Technique

We sought to capture both long- and short-term dynamics in environmental quality across 34 provinces in Indonesia from 2015-2023 using the Panel Error Correction Model (PECM). The analytical framework is a modification of Sikder et al. (2022), which was adapted to the Indonesian context by integrating democracy, socio-economics, and financial development factors that reflect provincial-level economic activity. This modification provides a more comprehensive understanding of the correlation between regional economic development and environmental sustainability. Conceptually, the model can be described as follows:

$$\begin{aligned} \Delta EQI_{it} = & \beta_0 + \beta_1 \Delta DEMO_{it} + \beta_2 \Delta LNPOP_{it} + \\ & \beta_3 \Delta EDUC_{it} + \beta_4 \Delta LNWAGE_{it} + \beta_5 \Delta POV_{it} + \beta_6 \Delta FI_{it} + \\ & \beta_7 \Delta DI_{it} + \beta_8 \Delta GRDP_{it} + \beta_9 DEMO_{it-1} + \beta_{10} LNPOP_{it-1} \\ & + \beta_{11} EDUC_{it-1} + \beta_{12} LNWAGE_{it-1} + \beta_{13} POV_{it-1} + \\ & \beta_{14} FI_{it-1} + \beta_{15} DI_{it-1} + \beta_{16} GRDP_{it-1} + \lambda ECT_{it-1} + \\ & \varepsilon_{it} \dots(1) \end{aligned}$$

Table 1 summarizes the operational definitions of all variables used in this study and provides information on their respective measurement units.

2.2. Data

The analysis used data on democracy indices, population density, education levels, wages, number of poor people, foreign investment, domestic investment, GRDP, and environmental quality indices for 34 provinces in Indonesia covering the period 2015-2023. The data sources included the Central Statistics Agency (BPS), the Ministry of Investment and Downstream Industry, and the Ministry of Environment

Table 1: Measurement variables.

Symbol	Definition / Unit
EQI	Provincial Environmental Quality Index
DEMO	Indonesian Democracy Index
LNPOP	Log of population density (persons per km ²)
EDUC	Average years of schooling (years)
LNWAGE	Log of average hourly wage (Rupiah/hour)
POV	Number of poor individuals (persons)
FI	Foreign investment (million Rupiah)
DI	Domestic investment (million Rupiah)
GRDP	GRDP at constant prices (billion Rupiah)

and Forestry. The researchers assume that Indonesia's democratic system consistently implements regional head elections (governors) and national elections every five years, with a maximum of two terms in office. This electoral cycle is expected to capture the factors affecting environmental quality in both the short and the long term. Consequently, the study results can serve as reference material for local governments in formulating targeted policies within a relatively limited governance timeframe, namely, a maximum of ten years.

2.3. Panel Unit Root Test

The first step of the analysis was to test for stationarity using the Im-Pesaran-Shin (IPS) and ADF-Fisher. This step is crucial, as non-stationary data may result in spurious regression and misinterpretation of findings (Pesaran 2007). The general form is as follows:

$$\begin{aligned} \Delta Y_t = & \delta Y_{t-1} + \mu_t \\ \Delta Y_t = & Y_t - Y_{t-1} \dots(2) \end{aligned}$$

Where ΔY_t denotes the change in the data, and δ is the parameter being tested.

Following the stationarity tests, cross-section dependence (CSD) was assessed to examine whether residuals across units are correlated, which may affect the validity of panel estimators. The Breusch-Pagan LM and Pesaran CD tests were applied to detect the presence of CSD. A correlation matrix was also computed to evaluate the linear relationships among the variables and identify potential multicollinearity issues. These diagnostic checks ensure that the subsequent estimation procedures are based on a well-behaved data structure (Sikder et al. 2022).

2.4. Panel Error Correction Model (PECM)

The ECM panel specification followed the approach of Domowitz and Elbadawi (1987) and could be formulated as:

$$\Delta Y_{it} = \beta_0 + \beta_1 \Delta X_{it} + \beta_2 \Delta X_{it-1} + \lambda ECT_{it-1} + \varepsilon_{it} \dots(3)$$

In this model, the adjustment coefficient (λ) is expected to lie between 0 and 1 ($0 < \lambda < 1$). The λ coefficient represents the speed of adjustment toward long-term equilibrium. The Error Correction Term (ECT) ensures that the system converges back to its long-term equilibrium state. After the stationarity tests, each variable must pass the first-difference stage.

$$EQI_{it} = \beta_0 + \beta_1 DEMO_{it} + \beta_2 LNPOP_{it} + \beta_3 EDUC_{it} + \beta_4 LNWAGE_{it} + \beta_5 POV_{it} + \beta_6 FI_{it} + \beta_7 DI_{it} + \beta_8 GRDP_{it} \dots(4)$$

Long-run modelling was then conducted to determine the ECT. Long-run effects were tested using common, fixed,

and random effects models. Subsequently, model selection was performed using the Chow and Hausman tests. Once the optimal long-term model was identified, the residuals were projected to obtain the ECT, which was then incorporated into the cointegration test to confirm the stability of the long-term relationship among the variables (Putra et al. 2025). The ECT coefficient must be statistically significant at the chosen significance level.

$$ECT = DEMO_{it-1} + LNPOP_{it-1} + EDUC_{it-1} + LNWAGE_{it-1} + \beta_5 POV_{it-1} + FI_{it-1} + DI_{it-1} + GRDP_{it-1} \dots(5)$$

Table 2: Descriptive analysis.

Variabel	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Observations
EQI	69.405	70.815	85.690	35.780	8.650	-1.004	4.266	306
DEMO	74.734	75.470	89.210	54.410	6.014	-0.519	3.153	306
LNPOP	4.888	4.630	9.684	2.197	1.580	0.717	3.816	306
EDUC	8.935	8.955	11.420	6.270	0.882	0.018	3.227	306
LNWAGE	9.706	9.685	10.654	9.051	0.256	0.390	3.216	306
POV	789.185	366.160	4789.120	39.690	1113.712	2.489	8.096	306
FI	13911995	5830975	122599431	25332	20486738	2.478	9.694	306
DI	11304030	4969470	95202092	8772	16326363	2.544	10.075	306
LNGRDP	11.955	11.810	14.534	9.922	1.141	0.487	2.568	306

Table 3: Panel unit root tests.

Variable	IPS		ADF	
	Level	1st Difference	Level	1st Difference
EQI	-0.043 (0.483)	-3.852 (0.000)***	63.801 (0.622)	12.905 (0.000)***
DEMO	-0.965 (0.167)	-7.543 (0.000)***	91.305 (0.031)**	180.549 (0.000)***
LNPOP	2.145 (0.984)	-4.596 (0.000)***	49.158 (0.959)	143.361 (0.000)***
EDUC	3.777 (0.999)	-5.811 (0.000)***	33.497 (0.999)	158.537 (0.000)***
LNWAGE	1.259 (0.896)	-5.835 (0.000)***	46.711 (0.977)	166.542 (0.000)***
POV	0.0496 (0.519)	-2.047 (0.020)**	63.609 (0.628)	95.291 (0.016)**
FI	-1.095 (0.137)	-5.889 (0.000)***	93.367 (0.022)**	180.972 (0.000)***
DI	1.578 (0.943)	-7.012 (0.000)***	65.499 (0.564)	189.327 (0.000)***
LNGRDP	3.349 (0.996)	-2.652 (0.004)***	28.849 (0.998)	103.222 (0.003)***

*significant at 10% α , **significant at 5% α , ***significant at 1% α .

The short-run dynamics were modelled using the selected long-run specification, which was then estimated along with the ECT. The general form of the short-run model was as follows:

$$\begin{aligned} \Delta EQI_{it} = & \beta_0 + \beta_1 \Delta DEMO_{it} + \beta_2 \Delta LNPOP_{it} + \\ & \beta_3 \Delta EDUC_{it} + \beta_4 \Delta LNWAGE_{it} + \beta_5 \Delta POV_{it} + \\ & \beta_6 \Delta FI_{it} + \beta_7 \Delta DI_{it} + \beta_8 \Delta GRDP_{it} + \lambda ECT_{it-1} + \varepsilon_{it} \end{aligned} \quad \dots(6)$$

3. RESULTS AND DISCUSSION

3.1. Results

As presented in Table 2, the descriptive analysis shows that the mean value of the EQI was 69.405, with the minimum and maximum values recorded at 35.780 and 85.690, respectively. The average Democracy Index was 74.734, while the average Population Density (LNPOP) was 4.888, indicating substantial variation across provinces. The average level of education (EDUC) was 8.935 years, whereas wages (LNWAGE) were more homogeneous, with an average of 9.706 years. The average number of poor people (POV) was 789,185, reflecting a high disparity. Foreign Investment (FI) and Domestic Investment (DI) averaged 13,911,995

million rupiah and 11,304,030 million rupiah, respectively. The average GRDP value was 11,955 billion rupiah. A stationarity test was then conducted on all variables used to measure environmental quality across 34 provinces in Indonesia during the period 2015-2023.

Table 3 shows that all variables were stationary at the first difference, thereby meeting the requirements for use in PECM. In the next stage, a long-term regression was performed to determine ECT (see Table 4). The F-statistic probability was 0.000 (< 0.01), and the χ^2 statistic probability was also 0.000 (< 0.01). Thus, the fixed-effects model was selected, and the residual value was proxied as the ECT. Table 3 further shows that the ECT passed the cointegration test, as indicated by the IPS, ADF, and PP statistics, which were -3.991, 126.183, and 150.794, respectively, with a probability of 0.000 (< 0.01). These results confirm that the variables used in this study exhibited a cointegration relationship.

Table 5 presents the correlation matrix, showing that correlations among variables were generally low to moderate, suggesting no serious multicollinearity concerns. Although several economic variables such as LNGRDP, FI, and DI exhibit correlations above 0.6, these values remain below the conventional thresholds typically associated with harmful

Table 4: Identifying ECT and cointegration test.

Model Selection Test				
Methods	Statistic	Std. Error	Prob.	Conclusions
Chow	F (33,264) = 7.934	5.108	0.000***	Fixed Effects
Hausman	$\chi^2(8) = 67.499$	3.839	0.000***	Fixed Effects
Cointegration Test				
Methods	Statistic		Prob.	Conclusions
IPS	-3.991		0.000***	Passed the level stage and has a cointegration relationship
ADF	126.183		0.000***	
PP	150.794		0.000***	

*significant at 10% α , **significant at 5% α , ***significant at 1% α .

Table 5: Correlation matrix of the variables.

	EQI	DEMO	LNPOP	EDUC	LNWAGE	POV	FI	DI	LNGRDP
EQI	1								
DEMO	-0.185	1							
LNPOP	-0.762	0.349	1						
EDUC	-0.089	0.280	0.241	1					
LNWAGE	0.218	0.058	-0.122	0.482	1				
POV	-0.335	-0.019	0.446	-0.288	-0.307	1			
FI	-0.354	0.127	0.452	0.163	0.250	0.464	1		
DI	-0.423	0.290	0.561	0.207	0.213	0.590	0.685	1	
LNGRDP	-0.551	0.178	0.612	0.145	0.086	0.656	0.613	0.774	1

multicollinearity, and they do not reach the levels ($>0.80-0.90$) that would indicate near-linear dependence (Sikder et al. 2022). As part of the robustness check, Table 6 reports the results of cross-section dependence tests using the Pesaran CD (2004) and Breusch-Pagan LM (1980) methods, both of which showed statistical significance at the 1% level for all variables. These findings indicate the presence of cross-sectional interdependence in the panel data structure.

Finally, Table 7 shows that both the long-term and short-term effects in the model are valid, as indicated by the significant ECT coefficient of 0.576 ($p\text{-value} = 0.000 < 0.01$). This coefficient suggests that approximately 57.6% of any disequilibrium is corrected within one period, implying that the system requires about 1.7 years to return to its long-run equilibrium after a shock. In the short term, GRDP, which reflects macroeconomic activity, was found to have

Table 6: Cross-section dependence test.

Variable	Pesaran CD Test	Prob.	Breusch-Pagan LM Test	Prob.
EQI	27.892	0.000***	1,479.599	0.000***
DEMO	13.905	0.000***	949.689	0.000***
LNPOP	50.896	0.000***	3,133.075	0.000***
EDUC	69.843	0.000***	4,879.403	0.000***
LNWAGE	59.243	0.000***	3,617.227	0.000***
POV	16.747	0.000***	1,930.167	0.000***
FI	5.052	0.000***	756.507	0.000***
DI	36.223	0.000***	1,725.845	0.000***
LNGRDP	67.372	0.000***	4,579.004	0.000***

*significant at 10% α , **significant at 5% α , ***significant at 1% α .

Table 7: The results of Panel ECM: Long and Short-run.

Long-run				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	134.985	45.943	2.938	0.004
DEMO	0.129	0.065	1.982	0.049**
LNPOP	-16.190	6.177	-2.621	0.009***
EDUC	12.288	2.112	5.818	0.000***
LNWAGE	-0.482	2.601	-0.185	0.853
POV	0.006	0.003	2.303	0.022**
FI	0.000	0.000	1.103	0.271
DI	0.000	0.000	2.770	0.006***
LNGRDP	-8.984	4.609	-1.949	0.052*
Short-run				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(DEMO)	0.057	0.051	1.113	0.267
D(LN(POP))	-8.669	8.433	-1.028	0.305
D(EDUC)	5.402	3.905	1.384	0.168
D(LN(WAGE))	-2.412	2.081	-1.159	0.248
D(POV)	0.004	0.003	1.289	0.199
D(FI)	0.000	0.000	0.205	0.838
D(DI)	0.000	0.000	-0.528	0.598
D(LN(GRDP))	-31.495	7.594	-4.147	0.000***
ECT	0.576	0.068	8.482	0.000***
R ²	0.341	-	Adjusted R ²	0.219

*significant at 10% α , **significant at 5% α , ***significant at 1% α .

Table 8: The robustness test.

Heteroscedasticity	Coefficient	Prob.	Autocorrelation	Coefficient	Prob.
C	2.464	0.000	C	-0.646	0.306
D(DEMO)	-0.008	0.775	D(DEMO)	0.011	0.862
D(LN(POP))	3.106	0.503	D(LN(POP))	0.434	0.959
D(EDUC)	2.643	0.219	D(EDUC)	7.234	0.082
D(LN(WAGE))	-0.558	0.626	D(LN(WAGE))	0.657	0.796
D(POV)	-0.001	0.554	D(POV)	0.001	0.782
D(FI)	0.000	0.102	D(FI)	0.000	0.911
D(DI)	0.000	0.061	D(DI)	0.000	0.839
D(LN(GRDP))	-2.864	0.493	D(LN(GRDP))	3.121	0.694
ECT	-0.005	0.889	ECT	0.095	0.299
			RESID_1	-0.050	0.497
			RESID_2	-0.046	0.495

a significant effect on the EQI, while other variables showed no significant short-term effects. In contrast, the long-term analysis demonstrates that DEMO, LNPOP, EDUC, POV, DI, and GRDP significantly affected the EQI across the 34 provinces of Indonesia during 2015-2023.

Table 8 presents a series of model robustness tests conducted to ensure the reliability of the Panel ECM estimates. The first section presents the results of the heteroscedasticity test. All explanatory variables in the differentiated form do not show statistical significance at the general testing level, indicating that the residual dispersion is relatively consistent across observations. Thus, there is no evidence to suggest the presence of heteroscedasticity in the model. The second part evaluates the presence of autocorrelation by adding lagged residuals, namely RESID(-1) and RESID(-2), to the regression. Both coefficients are insignificant ($p > 0.05$); therefore, it can be concluded that the model is free from autocorrelation in both the first and second orders. The error correction term (ECT) also remains stable, indicating no dynamic specification inaccuracy. Overall, the results of this test confirm that the Panel ECM model meets the necessary basic assumptions, so that the empirical findings can be considered robust and methodologically valid.

3.2. Discussion

3.2.1. The Influence of Democracy and Education

In the short term, the democracy index has no significant effect on the EQI. However, in the long term, it has a positive effect. A coefficient of 0.129 indicates that a one-unit increase in the democracy index leads to a 0.13-unit increase in the EQI. These findings confirm the hypothesis and align with the results of Hasan et al. (2025), who reported

that increases in the democracy index tend to improve the EQI. This suggests that improvements in governance, such as transparency, participation, and accountability, require time for effective integration into public policy, with impacts materializing only in the long term. In addition, education level has a strong positive impact in the long term. A coefficient of 12.288 indicates that an average increase of one year of education among the population can improve environmental quality by 12.3 units. These results indicate that democratic systems create mechanisms for participation, openness, and public control, whereas education equips citizens with the knowledge and ecological awareness to utilize these mechanisms effectively. When these two factors work together, communities are in a stronger position to promote, monitor, and maintain environmentally friendly policies, thereby ensuring consistent improvements in environmental quality over time.

3.2.2. Demographic Pressure and the Threat of Environmental Degradation

Population density had no significant short-term effect. However, in the long term, it negatively affected the EQI score. A coefficient of -16.190 suggests that a 1% increase in population density reduces the EQI by 0.16 units. These findings support the hypothesis and are consistent with Li et al. (2025) and Suhrab et al. (2025), both of which emphasize the importance of population control and sustainable density management to mitigate environmental stress. However, although population density often reflects people's preference for cities with higher wages, empirical analysis shows that wage levels do not significantly affect the EQI. This indicates that environmental degradation in urban areas is controlled more by population loads that exceed the capacity of environmental services, such as

sewage systems, green open spaces, and air quality, than by residents' income levels.

3.2.3. *The Dynamics of Poverty*

The number of people living in poverty improved the EQI score. The long-term coefficient of 0.006 indicates that an increase of 100,000 people in poverty corresponds to a 0.6 unit rise in the EQI. Conversely, reducing the number of poor people by 100,000 leads to a 0.6 unit decline in the EQI. This counterintuitive result aligns with the poverty-environment trap phenomenon described by Dao & Edenhofer (2018) and Giannetti et al. (2023), who found that poverty can mitigate the pressure of exploitation on the environment due to limited production and consumption capacity. In such contexts, poor communities tend to limit consumption because of their restricted purchasing power, which results in relatively low levels of environmentally damaging activity. Consequently, the environment may appear "better preserved," not because of proactive protection policies or sustainability awareness, but due to the limited ability of impoverished communities to exploit natural resources intensively.

3.2.4. *The Role of Financial Development*

Our findings show that financial development, as represented by foreign and domestic investments, has little impact on environmental quality. The analysis of investment variables indicates that only domestic investment has a positive long-term effect on the EQI. The regression coefficient of 0.000000956 suggests that an increase of 100 billion rupiah in domestic investment raises the EQI by 0.00956. Although this finding confirms the positive role of domestic investment, the magnitude of the effect remains very small, underscoring that its contribution to sustainability is still in its early stages. Our results are in line with those of Minh et al. (2023) and Mtar et al. (2025), who explained that environmental benefits only emerge when investments are explicitly directed towards clean energy, green infrastructure, or low-emission technologies. These findings indicate that provincial investment flows have not been allocated to economic activities that can strengthen environmental capacity. The vast tropical forests in Indonesia have significant ecological capacity to absorb pollutants and mitigate some of the pressure of emissions from economic activities. However, this natural capacity cannot be used as a basis for delaying corrective actions. The government needs to view these findings as an important signal that investment potential, both domestic and foreign, must be directed more strategically to not only drive economic growth but also strengthen environmental sustainability in the long term.

3.2.5. *GRDP and Environmental Quality*

The empirical estimates show that economic expansion, as

measured by GRDP, is associated with a deterioration in environmental quality both immediately and over longer horizons. In the short term, the coefficient of -31.495 implies that a 1% increase in GRDP reduces the environmental index by 0.32. This relatively strong effect is likely driven by short-lived surges in resource extraction, energy consumption, and industrial activity, which typically accompany economic upswings. When the analysis is extended to the long run, the adverse impact remains but becomes noticeably weaker. In the long term, the magnitude of the effect decreases, with a coefficient of -8.984, meaning that a 1% increase in GRDP lowers the environmental index by 0.09 units. This attenuation suggests that, over time, economies gradually incorporate mechanisms that soften environmental pressures, such as cleaner technologies, enhanced regulatory oversight, and a shift away from highly polluting sectors.

Taken together, the findings are broadly consistent with the early dynamics predicted by the Environmental Kuznets Curve (EKC) (Kuznets 1955). Although GRDP currently exerts a negative effect on environmental quality, the substantial reduction in the long-run coefficient indicates that the environmental burden of economic expansion diminishes as development advances. In the EKC framework, this weakening of the adverse effect represents the initial phase in which efficiency improvements, regulatory tightening, and structural shifts begin to offset the environmental pressures generated by income growth. Although the present sample period is not long enough to detect a complete inverted-U shape or identify a formal turning point, the trajectory of the coefficients suggests that the economy may be moving toward it. The steady decline in the magnitude of the negative impact implies that, over a longer developmental horizon, the detrimental effect of GRDP on environmental quality could continue to diminish and may eventually be reversed. This pattern aligns with the EKC hypothesis, in which environmental degradation first intensifies and then gradually improves as economies adopt cleaner technologies, diversify from carbon-intensive sectors, and strengthen environmental governance mechanisms.

To further explore this dynamic, we analyzed which GRDP-forming sectors in the 34 provinces most significantly affected EQI, as shown in Table 9.

SECTOR: A. Agriculture, Forestry, and Fisheries, B. Mining and Quarrying, C. Manufacturing, D. Electricity and Gas Supply, E. Water Supply, Waste Management, Waste and Recycling, F. Construction, G. Wholesale and Retail Trade, Car and Motorcycle Repair, H. Transportation and Warehousing, I. Provision of Accommodation and Food and Beverages, J. Information and Communication, K. Financial and Insurance Services, L. Real Estate, M. N. Service Companies, O. Government Administration, Defense, and

Table 9: GRDP Sectoral on Environmental Quality Index.

Variable	CEM		FEM		REM	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	68.455	0.000	140.433	0.012	66.435	0.000
LN(SECTOR_A)	-0.305	0.617	2.121	0.775	-0.471	0.647
LN(SECTOR_B)	0.339	0.345	-6.016	0.012**	0.936	0.145
LN(SECTOR_C)	-0.449	0.394	5.795	0.002***	0.304	0.715
LN(SECTOR_D)	-2.581	0.003	0.780	0.800	-4.536	0.001
LN(SECTOR_E)	4.440	0.000	1.076	0.863	4.626	0.000
LN(SECTOR_F)	3.763	0.006	-4.590	0.392	0.042	0.985
LN(SECTOR_G)	3.184	0.099	0.341	0.960	5.717	0.054
LN(SECTOR_H)	-1.606	0.097	1.439	0.664	-3.147	0.038
LN(SECTOR_I)	0.363	0.526	-6.011	0.179	-0.494	0.636
LN(SECTOR_J)	-1.605	0.136	14.384	0.000***	5.136	0.004
LN(SECTOR_K)	-10.438	0.000	-4.434	0.375	-10.125	0.000
LN(SECTOR_L)	-1.515	0.005	-0.587	0.928	-2.368	0.020
LN(SECTOR_MN)	-0.538	0.230	-9.269	0.010**	-1.791	0.017
LN(SECTOR_O)	2.558	0.059	-28.459	0.000***	-2.981	0.207
LN(SECTOR_P)	-2.863	0.028	16.691	0.018**	-4.087	0.079
LN(SECTOR_Q)	7.595	0.000	7.115	0.065*	13.333	0.000
R ²	0.639		0.852		0.352	
Adj. R ²	0.619		0.824		0.316	
Prob.(F-stat)	0.000		0.000		0.000	

Chow Test $F(33, 256) = 11.217$, Prob. $F = 0.000***$; Hausman Test Cross-section random $\chi^2(16) = 126.694$, Prob. $\chi^2 = 0.000***$; *significant at 10% α , **significant at 5% α , ***significant at 1% α .

Compulsory Social Security, P. Educational Services, Q. Health Services and Social Activities.

3.3. Sector Analysis

The sectoral analysis revealed that the Fixed Effects Model (FEM) was selected as the best-fitting model, supported by the Prob. F of 0.000 and Prob. χ^2 of 0.000. The results indicate that the Manufacturing, Information and Communication, Education Services, Health Services, and Social Activities sectors had a positive effect on the EQI. In contrast, the Mining and Quarrying, Business Services, Public Administration, Defense, and Compulsory Social Security sectors had negative effects on the EQI across the 34 provinces in Indonesia from 2015 to 2023.

3.3.1. Sector B. Mining and Quarrying

The mining and quarrying sector reduces the EQI by 0.06 units. As highlighted in the resource curse literature by Muhamad and Khezri (2025), extractive activities such as coal, nickel, mineral, and petroleum exploitation contribute to deforestation, water pollution, biodiversity loss, and land degradation. Although this sector remains

a major pillar of Indonesia's foreign exchange earnings, the environmental costs significantly outweigh its short-term economic benefits. This negative contribution underscores the classic dilemma between economic growth driven by natural resource extraction and environmental sustainability.

3.3.2. Sector C. Manufacturing

The manufacturing sector contributes positively to the EQI, with an increase of approximately 0.06 units, which seems contradictory to the conventional view that associates industry with pollution. However, from 2015 to 2023, many manufacturing companies in Indonesia underwent significant transformations towards cleaner and more ecologically efficient production models. Most have adopted green industry practices, such as waste management, energy efficiency, and environmental management systems that meet Green Industry Standards. The Ministry of Industry (Kemenperin) is actively promoting these initiatives through energy conservation policies (PP No. 33 of 2023) and programs such as the Boosting Energy Efficiency Practices for the Industrial Sector (BENEFITS) project,

which strengthens energy management in manufacturing plants (Nurcahyanto et al. 2020). Additionally, the government has formulated an Industrial Decarbonization Roadmap that targets the manufacturing sector to achieve net-zero emissions by 2050 through the use of low-carbon technologies, material efficiency, and the circular economy. At the company level, several factories have achieved Green Industry certification as proof of their commitment to environmentally friendly practices.

3.3.3. Sector J. Information and Communication

Sector J increases the EQI by 0.14 units. The information and communication sector positively contributed to environmental quality because its activities were predominantly digital, producing minimal pollution or physical waste. The digitalization of economic activity has promoted efficiency by reducing paper consumption, lowering physical mobility through remote working arrangements, and encouraging online services to reduce transportation-related emissions. Moreover, communication technologies have facilitated the dissemination of environmental knowledge and supported transparency in public policy. Thus, although indirect, the sector plays a strategically significant role in improving environmental quality.

3.3.4. Sector MN. Corporate Services

The business services sector was identified as having reduced the EQI by 0.09. This is largely attributable to its reliance on resource- and energy-intensive activities, such as business travel, logistics, and project construction. In the absence of environmental cost internalization, these activities indirectly degrade ecosystem conditions. Furthermore, the limited adoption of Environmental, Social, and Governance (ESG) principles in corporate practices has constrained this sector's potential to contribute positively to environmental sustainability.

3.3.5. Sector O. Public Administration, Defense, and Mandatory Social Security

Sector O reduces the EQI by 0.29 points; the negative contribution of this sector reflects the limited integration of green governance into bureaucratic and institutional practices. Provincial government agencies rely heavily on fossil fuels, inefficient resource use, and weak internal policies regarding energy conservation and waste reduction. In addition, budget allocations for defense and social security tend to neglect explicit provisions for advancing the green economic transition. These findings highlight the urgent need for institutional reform to ensure that the public sector not only acts as a regulator but also serves as a role model for adopting environmentally responsible practices.

3.3.6. Sector P. Education Services

GRDP in the education services sector has been shown to increase the EQI by 0.16 units, which is consistent with our initial long-term findings (see Table 7). The positive effect of the education sector on the EQI highlights the crucial role of education in fostering ecological awareness. Broader access to and improved quality of education can enhance knowledge of clean technologies and cultivate a generation that is more attentive to sustainability challenges. According to Todaro and Smith (2020), education is often regarded as the "fourth pillar" of sustainability, as it develops human capital that drives green innovation. Hence, the contribution of the education sector to environmental quality is direct and long-term, as it promotes changes in values, mindsets, and behaviors that underpin sustainable development.

3.3.7. Sector Q. Health Services and Social Activities

The health sector has been recorded as having a positive impact on the EQI, with an increase of approximately 0.07 units. This is understandable because better health services usually encourage the community to be more concerned about environmental quality, ranging from the need for clean air to the importance of safe waste disposal. Social activities further reinforce this link by encouraging community participation in environmental protection through reforestation, community-based waste management, and environmental awareness campaigns. These positive dynamics illustrate a reciprocal relationship: a healthy environment enhances public health outcomes, while growing health consciousness creates stronger public demand for improved environmental conditions.

3.4. Policy Implications

Based on the empirical findings regarding the determinants of environmental quality across 34 provinces in Indonesia, it is essential to formulate policy recommendations that can guide both central and regional governments in designing sustainable development strategies.

3.4.1. National Level

Strengthening green industry regulation should be prioritized by aligning it with the Medium-Term National Development Plan (RPJMN), supported by fiscal incentives or dedicated financing for sectors that adopt low-emission technologies and improve resource efficiency. In line with the government's green fiscal reform agenda, the fiscal transfer mechanism, particularly the Special Allocation Fund (DAK) and the Regional Incentive Fund (DID), should be revised to incorporate the EQI as a performance indicator, thereby encouraging local governments to enhance their environmental management. Moreover, although financial

development only has long-term effects, this sector must still be guided to prevent environmental pressure.

3.4.2. Regional Level (Provinces)

At the provincial level, it is essential to incorporate environmental performance indicators into the evaluation of local government effectiveness, especially under the Low Carbon Development Planning (PPRK) framework, which the majority of provinces has implemented. Local authorities should design action plans tailored to the specific characteristics of their regions, prioritizing sectors that most strongly influence the EQI, such as the energy sector in Java, extractive industries in Sumatra and Kalimantan, and agricultural activities in Nusa Tenggara and Sulawesi.

3.4.3. Synergy Between Central and Regional Governments

Coordination between central and local governments should be strengthened to enhance the effectiveness of environmental policies in Indonesia. Provincial energy and green economy transition strategies should be aligned with national emission reduction targets to ensure consistency across governance levels. Cross-government Monitoring, Reporting, and Verification (MRV) systems should be enhanced to support carbon management, emission control, and climate mitigation initiatives. Furthermore, environmental quality should be established as one of the key performance indicators of regional development.

4. CONCLUSIONS

We analyzed the influence of democracy, socioeconomic dynamics, and GRDP sectoral structure on environmental quality in 34 provinces in Indonesia from 2015 to 2023. Our findings show that democracy indices, education levels, poverty, and domestic investment improve the EQI, whereas GRDP and population density worsen it. Furthermore, extractive industries, business services, and government administration reduced the EQI. Meanwhile, the economic sectors of manufacturing, information and communication, education, and health were found to improve the EQI.

Our findings support the EKC hypothesis, which posits that environmental quality initially declines during the early stages of economic growth before improving as development progresses, as reflected in the smaller long-term effects compared to short-term effects. The results further indicate that substantive democracy, human capital development, and growth of environmentally friendly service sectors are crucial for achieving regional environmental sustainability. Therefore, economic development should not rely solely on output expansion but should also promote sectoral diversification to reduce dependence on extractive industries. Hence, economic development should not only rely on

output expansion but also encourage sectoral diversification to reduce dependence on extractive industries. In addition, financial development must continue to pay attention to environmental quality so that it does not have a negative long-term impact.

This study had certain limitations that need to be acknowledged. First, the relatively short nine-year period may restrict the ability to capture long-term trends in environmental outcomes. Second, relying on aggregated provincial data may mask variations within provinces and obscure local-level dynamics. Third, the absence of detailed sectoral foreign direct investment information limits the analysis of differential impacts across industries. Further research is expected to overcome these constraints by extending the period of analysis and utilizing more disaggregated data. Incorporating spatial econometric techniques allows for the consideration of inter-regional spillovers, while using composite governance measures, such as an environmental democracy index, could provide a more comprehensive assessment of institutional influences on environmental quality.

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