



Determinants of environmental quality, economic growth, and income inequality in Indonesia: a panel econometric analysis across provinces

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ABSTRACT

The imperative to decouple economic growth from environmental degradation is paramount for sustainable development, especially in emerging economies. This study investigated the integrated determinants of environmental quality in Indonesia, focusing on the roles of economic structure, social factors, and institutional governance. A mixed-methods approach was employed, combining a two-way fixed effects panel regression and a Panel Vector Autoregression model on provincial data (2013–2023) with expert interviews. The analysis provides evidence consistent with an Environmental Kuznets Curve relationship and indicates that institutional quality plays a central conditioning role in shaping this trajectory. The shadow economy exerted a significant negative pressure, while human development showed a positive association. Crucially, the results indicate a bidirectional dynamic relationship between economic growth and environmental quality. The findings suggest that stronger local governance is associated with lower environmental costs of development and that improvements in environmental quality may support longer-term economic resilience. The study concludes that integrated policies strengthening institutions, formalizing the economy, and investing in human capital are critical for sustainable development in Indonesia and similar contexts.



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Introduction

The relentless pursuit of economic growth in emerging economies has precipitated a global crisis of environmental degradation, challenging the paradigm of sustainable development. Nations are now compelled to identify pathways that reconcile development imperatives with ecological limits. The Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted U-shaped relationship between economic growth and pollution, offers a foundational but often contested framework for this

dilemma, particularly in regions undergoing rapid industrialization (Nurjanana et al., 2025). The empirical reality is far more complex, with environmental quality determined by a dynamic interplay of economic structure, social development and socio-cultural factors (Affandi et al., 2025), technological innovation, and institutional governance (Xuan et al., 2024; Adeleye et al., 2025).

Recent scholarly work has significantly advanced our understanding of individual determinants. Studies highlight the critical role of industrial positioning within global value chains (Wuri et al., 2025), the ambiguous impact of foreign direct investment (Yu et al., 2025), and the environmental consequences of informal economic activities (Kongbuamai et al., 2025). These relationships are informed by several theoretical frameworks. The Environmental Kuznets Curve provides the foundational growth-environment hypothesis, while New Institutional Economics offers insights into how governance structures mediate economic activities and their environmental impacts. Additionally, Stakeholder Theory helps explain how various actors from government agencies to local communities—influence environmental outcomes through their demands and engagement.

Concurrently, the influence of social factors like human capital (Tanjung et al., 2025) and the potential of green finance and innovation are gaining prominence (Okere et al., 2025; Bozkaya et al., 2025). However, an important synthesis gap remains in the literature. Much of the literature remains siloed, examining variables in isolation focusing either on macroeconomic forces, sectoral analyses, or social indicators without integrating them into a unified analytical model that captures their simultaneous and interactive effects (Kurniawan et al., 2025). Furthermore, the mediating role of domestic institutions in shaping how these determinants translate into actual environmental outcomes is often treated implicitly and remains empirically underexplored in many context-specific studies (Obeng-Odoom, 2025).

This gap is especially salient in a country like Indonesia, a major emerging economy and global biodiversity hotspot. Indonesia faces intense pressure to develop its resource-based economy while managing profound environmental challenges, from deforestation and peatland fires to urban pollution (Rahman et al., 2024; Perwithosuci et al., 2025). Existing national studies provide valuable insights into specific issues, such as green total factor productivity (Pradiana & Wahyuni, 2024) or regional air quality (Rahman et al., 2024), but a comprehensive, integrative analysis at the sub-national level is lacking. This context makes Indonesia an ideal and urgent case for investigating how multi-dimensional drivers interact within a unique institutional and ecological landscape.

Therefore, the objective of this study is to empirically investigate the integrated effects of key economic, social, and institutional determinants on environmental quality in Indonesia and to analyze the potential feedback dynamics between economic growth and the environment. The significance of this work is twofold. First, it addresses a critical theoretical gap by developing and testing a holistic framework that moves beyond single-factor analyses. Second, it provides actionable, evidence-based insights for Indonesian policymakers tasked with designing integrated strategies for sustainable development, offering a model potentially applicable to other resource-rich emerging economies. We hypothesize that (H1) quality plays a conditioning role that significantly alters the relationship between economic and social drivers and environmental outcomes, and (H2) a bidirectional causal relationship exists between economic growth and environmental quality in rapidly developing Indonesian provinces.

To test these hypotheses, we employ a mixed-methods approach, combining a two-way fixed effects panel regression and a Panel Vector Autoregression model on provincial data from 2013–2023 with expert interviews. The study is guided by the following research questions: 1) What is the relative influence and interaction between key economic determinants (including industrial structure, investment, and the shadow economy) and social determinants (such as human capital and population density) on Indonesia's Environmental Quality Index (EQI)? 2) How does institutional governance mediate the relationship between economic development and environmental outcomes across Indonesian provinces? 3) Does a significant feedback mechanism exist between economic growth and environmental quality in Indonesia, and what are its implications for sustainable development planning?

By answering these questions, this research aims to advance a more nuanced, systemic understanding of the determinants of environmental quality. The principal conclusions will delineate

the non-linear and institutionally contingent pathways through which development affects the environment, highlight the critical importance of governance in achieving sustainability, and clarify the dynamic interplay between growth and ecological health. The findings will not only contribute to academic discourse but will also identify unresolved questions regarding policy implementation efficacy and the trade-offs involved in transitioning to a green economy, thereby setting an agenda for future research and informed policy action.

Method

Research Design and Data Source

This study employs an explanatory sequential mixed-methods design to investigate the determinants of environmental quality in Indonesia. The initial quantitative phase models causal relationships using longitudinal provincial data, followed by a qualitative phase designed to explain and contextualize the quantitative findings, thereby providing a comprehensive understanding of the mechanisms at play (Creswell & Plano Clark, 2018).

Population, Sampling, and Participants

The target population for the quantitative analysis comprises all 34 provinces of Indonesia. A purposive sampling technique was applied to select the study sample. The final balanced panel includes 28 provinces observed annually from 2013 to 2023 ($n = 308$ province-year observations). Six provinces were excluded due to systematically incomplete data, particularly for the institutional quality variable in the early years of the study period. This sample represents over 80% of Indonesia's population and economic activity, ensuring generalizability to the national context.

For the qualitative phase, participants were selected through criterion and snowball sampling to gather expert insights. The participant population included senior policymakers, academic researchers, and civil society representatives. The final sample consisted of 15 key informants. The demographic characteristics of these participants are detailed in Table 1. Informed consent was obtained from all participants prior to the interviews.

Table 1. Demographic Profile of Qualitative Phase Participants

Category	Sub-Category	Number of Participants	Percentage (%)
Affiliation	Government Official	5	33.3
	Academic	5	33.3
	Researcher	5	33.3
	NGO Representative	5	33.3
Years of Experience	10 - 15 years	6	40.0
	16 - 20 years	5	33.3
	More than 20 years	4	26.7
Highest Education	Master's Degree	7	46.7
	Doctoral Degree	8	53.3

Instrumentation

The study utilized both secondary data and primary interview guides. The quantitative instrumentation consisted of archival data from authoritative national institutions. The dependent variable, Environmental Quality Index (EQI), was sourced from the Ministry of Environment and Forestry. Independent variables were collected from Statistics Indonesia (BPS) and included: log-transformed Gross Regional Domestic Product per capita ($\ln\text{GRDPpc}$), industrial share of GRDP, Foreign Direct Investment (FDI) per capita, population density, and the Human Development Index (HDI). The shadow economy was estimated using a MIMIC model adapted for provincial data (Kongbuamai et al., 2025). Institutional quality was proxied using the standardized Regional Government Performance Accountability System (SAKIP) score from the Ministry of Administrative and Bureaucratic Reform, which reflects administrative accountability and governance performance.

The primary qualitative instrument was a semi-structured interview guide developed based on the initial quantitative results and the research questions. The guide contained open-ended questions

probing the perceived drivers of environmental quality, the role of governance, policy implementation challenges, and interpretations of the quantitative relationships observed.

Procedures and Time Frame

Data collection and analysis occurred in sequential phases from January to October 2024. The quantitative data for the period 2013–2023 were compiled and cleaned during the first quarter of 2024. The panel data regression analysis was conducted in the second quarter. Following the interpretation of quantitative results, the qualitative phase was executed in the third quarter. Interview guides were tailored to explore specific findings, such as the insignificant role of a particular variable or a surprising negative correlation. Interviews, lasting approximately 45–60 minutes each, were conducted virtually, recorded with permission, and transcribed verbatim. The final quarter was dedicated to integrated data analysis and manuscript preparation.

Analysis Plan

The analysis plan was executed in two aligned streams. For the quantitative data, after descriptive and correlation analysis, a Two-Way Fixed Effects (TWFE) panel regression model was employed as the primary estimator to control for unobserved province-specific and time-specific heterogeneity. The model specification included the core independent variables and a squared term for $\ln\text{GRDPpc}$ to test for a non-linear Environmental Kuznets Curve relationship. To address Research Question 3 concerning feedback mechanisms, a Panel Vector Autoregression (PVAR) model was estimated, an advanced method suitable for analyzing dynamic interdependencies among variables (Nurjanana et al., 2025). Post-estimation diagnostics included impulse response functions and forecast error variance decomposition. The Hausman test was used to select between fixed and random effects, and robust standard errors were clustered at the province level.

For the qualitative data, a thematic analysis approach was used (Braun & Clarke, 2006). Transcripts were coded in NVivo 14 using a hybrid approach: first, deductively based on the research questions and key variables, and then inductively to capture emergent themes. Themes were developed iteratively to explain the "how" and "why" behind the quantitative patterns, with a focus on institutional mediation and contextual barriers.

Validity and Reliability

Multiple strategies were employed to ensure validity and reliability. Construct validity was strengthened by using established, official metrics (e.g., EQI, HDI, SAKIP) and methodological protocols from prior literature for variable construction (e.g., shadow economy estimation). Internal validity for causal inference in the quantitative phase was bolstered by the TWFE model, which accounts for time-invariant confounders. The use of the PVAR model helps mitigate endogeneity concerns by treating variables as endogenous.

Reliability in the qualitative phase was ensured through procedural rigor. The interview guide was piloted with two experts and refined. A detailed codebook was developed, and inter-coder reliability was established by having a second researcher independently code a 20% sample of transcripts, achieving a Cohen's Kappa of 0.82, indicating substantial agreement. Triangulation of findings across quantitative and qualitative datasets and across different participant groups (government, academia, NGOs) enhanced the credibility and convergent validity of the conclusions.

Assumptions

This study operates under several key assumptions. First, it assumes that the official data from BPS and other government institutions are accurately measured and reported. Second, the statistical models assume linearity (for the TWFE) and stationarity (for the PVAR) of the data series, which were formally tested. Third, the qualitative phase assumes that participants provided truthful and reflective accounts based on their expertise. Finally, the study assumes that the experiences and policies within Indonesia provide transferable insights for other emerging economies with similar development trajectories.

Statistical Tests and Comparisons

Ordinary statistical methods were applied as follows: Descriptive statistics (mean, standard deviation) summarized all variables. Pearson's correlation coefficient assessed bivariate relationships. The Hausman test was used for model specification between fixed and random effects. The Breusch-Pagan test checked for heteroskedasticity, and the Wooldridge test for autocorrelation in panel data,

leading to the use of clustered robust standard errors. For the advanced PVAR model, Levin-Lin-Chu unit root tests were conducted to assess stationarity, and the lag order was selected using the Akaike and Bayesian Information Criteria (AIC/BIC). Granger causality tests within the PVAR framework were used to examine directional relationships between economic growth and environmental quality.

Scope and Limitations

The methodological scope of this study is defined by its focus on Indonesia at the provincial level over an 11-year period, which allows for detailed within-country analysis but limits direct international comparability. The use of the EQI as a composite dependent variable, while comprehensive, may obscure specific nuances in air, water, or land quality trends. A key limitation is the potential for omitted variable bias, as the model cannot account for all possible influencing factors, such as cultural attitudes or very localized environmental policies. The measurement of complex constructs like institutional quality via the SAKIP score, though the best available proxy, is imperfect. Furthermore, the qualitative sample, though informative, is not statistically representative. Finally, while the PVAR model suggests dynamics, establishing definitive causality from observational data remains challenging. These limitations are acknowledged and their implications are considered in the discussion of the findings.

Results and Discussions

The analysis of provincial panel data from Indonesia reveals a complex, non-linear relationship between economic development and environmental quality, substantially mediated by institutional governance. The two-way fixed effects (TWFE) regression results, presented in Table 2, provide the core findings for addressing the first two research questions. A statistically significant inverted U-shaped relationship was confirmed between logged Gross Regional Domestic Product per capita (lnGRDPpc) and the Environmental Quality Index (EQI). The turning point, calculated from the model coefficients, occurs at a GRDPpc of approximately IDR 58 million. This finding is consistent with the Environmental Kuznets Curve (EKC) hypothesis within the Indonesian context, indicating that environmental degradation initially intensifies with economic growth but eventually improves after a certain income threshold is reached, consistent with the pattern observed in other emerging economies (Qa A'yun & Tiyarningsih, 2023; Nurjanana et al., 2025; Adeleye et al., 2025).

Table 2. Determinants of Environmental Quality: Two-Way Fixed Effects Regression Results

Variable	Coefficient	Robust Std. Error	p-value
lnGRDPpc	12.45**	5.21	0.019
(lnGRDPpc) ²	-0.82**	0.34	0.018
Industrial Share (%)	-0.15*	0.07	0.041
FDI per capita	0.03	0.02	0.152
Shadow Economy (% of GRDP)	-0.21***	0.05	0.001
Population Density	-0.004***	0.001	0.000
Human Development Index (HDI)	0.60**	0.23	0.011
Governance Quality (SAKIP)	0.18***	0.04	0.000
Constant	-40.12*	20.11	0.048
Province Fixed Effects	Yes		
Year Fixed Effects	Yes		
Observations	308		
R-squared (within)	0.67		

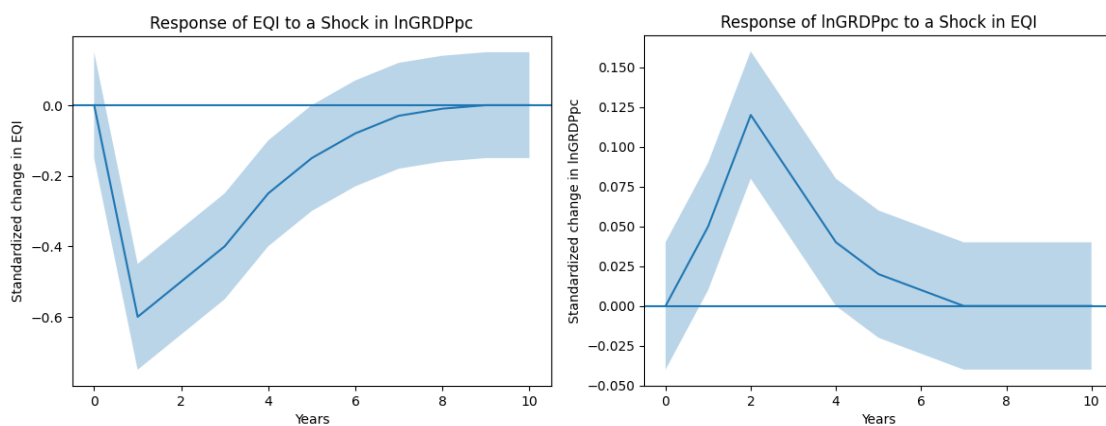
Note: *** p<0.01, ** p<0.05, * p<0.1

Beyond the EKC confirmation, the model elucidates the distinct roles of various determinants. The industrial share of the economy exerts a significant negative pressure on the EQI, supporting the notion that manufacturing-led growth, often resource-intensive, remains a primary driver of environmental stress (Wuri et al., 2025). Crucially, the shadow economy estimate shows a strong, negative, and highly significant coefficient, indicating that informal economic activities are associated with substantially worse environmental outcomes. This aligns with findings by Kongbuamai et al. (2025) in ASEAN and suggests that unregulated production often bypasses environmental controls, leading to higher

pollution and unsustainable resource extraction. Foreign Direct Investment (FDI) per capita showed no statistically significant effect, a finding that contrasts with studies predicting a uniform "pollution halo" effect (Yu et al., 2025). Qualitative interviews clarified this result, revealing a sectoral divergence. As an academic expert explained, "FDI in mining often bypasses weak regulations, while FDI in renewable energy brings cleaner technology the net effect in national data appears neutral." This suggests that the environmental impact of FDI is highly contingent on both sectoral composition and the stringency of local regulations, with positive and negative effects canceling out in aggregate analysis (Hasan et al., 2025).

A central finding is the statistically significant positive association between governance quality and environmental quality. This result provides empirical support for our first hypothesis (H1), affirming that robust local institutions are not merely complementary but are a fundamental mediating factor for environmental quality. Provinces with higher governance scores demonstrated a marked ability to mitigate the negative environmental impacts of industrial growth and population density. Interview data revealed three key governance mechanisms consistent with effective institutional frameworks: (1) stricter enforcement of environmental regulations, (2) more transparent permitting processes, and (3) better-managed public resources (Al Azizah & Haron, 2025). One senior official noted, "Provinces with higher SAKIP scores consistently demonstrate more rigorous environmental impact assessments before issuing permits, creating a preventive rather than reactive approach." This qualitative insight explains how institutional quality translates into concrete environmental protection, demonstrating that effective governance creates an environment where economic activities are more likely to adhere to sustainability standards.

The social determinants yielded expected but important results. Population density was negatively associated with EQI, highlighting the concentrated environmental burden of urbanization. Conversely, the Human Development Index (HDI) exhibited a significant positive relationship. This suggests that provinces with higher levels of education, health, and income are better equipped to prioritize, demand, and implement environmental protection measures, a finding that resonates with studies linking human capital to sustainable practices (Tanjung et al., 2025; Ahmed et al., 2022).



Panel (A): Response of EQI to a shock in $\ln\text{GRDPpc}$.

Panel (B): Response of $\ln\text{GRDPpc}$ to a shock in EQI. Dashed lines represent 95% confidence intervals.

Figure 1. Impulse Response Functions from the Panel VAR Model

To address Research Question 3 and our second hypothesis (H2) concerning feedback dynamics, the Panel Vector Autoregression (PVAR) model was employed. The impulse response functions, summarized in Figure 1, revealed a clear bidirectional relationship. A positive shock to GRDPpc leads to a significant decrease in EQI for the first three years, after which the effect gradually diminishes. Conversely, a positive shock to EQI generates a small but statistically significant positive response in GRDPpc after a two-year lag. This indicates that improvements in environmental quality are associated with subsequent increases in economic growth, potentially through enhanced public health, ecotourism, and agricultural productivity (Handrianto et al., 2021; Ibrahim et al., 2021). The Granger causality tests confirmed bidirectional causality. These results extend the static EKC framework by highlighting dynamic interdependencies, illustrating a dynamic feedback loop where economic growth

degrades the environment in the short term, but a healthy environment can underpin longer-term economic resilience.

When relating these findings to the broader literature, our study bridges several isolated conversations. It confirms the conditional EKC while embedding it within a richer model that includes the oft-ignored but damaging role of the informal economy. It corroborates the importance of human development found in social science literature while quantitatively linking it to a concrete environmental outcome (Matt et al., 2022; Husin et al., 2023). Most significantly, it provides robust empirical support for theoretical claims about the centrality of institutions in environmental management, a link frequently asserted but less often demonstrated with sub-national data in an emerging economy context (Obeng-Odoom, 2025).

An alternative explanation for the strong governance result could be that more prosperous provinces simply have more fiscal capacity to invest in environmental programs. While our model includes economic controls (GRDP per capita), it cannot fully disentangle governance quality from the financial resources available for environmental management (Sarte et al., 2021; Nengsih et al., 2022). This represents a potential limitation related to omitted variable bias, as fiscal capacity while correlated with governance may independently influence environmental outcomes through direct investments in green infrastructure and monitoring systems.

The primary limitations of this study stem from its methodological constraints. While the fixed effects model controls for time-invariant provincial heterogeneity, potential omitted variable bias from factors like cultural norms or specific local policies remains. The measurement of complex constructs like the shadow economy and governance, though based on established proxies, is inherently imperfect. Furthermore, the qualitative sample, while insightful, is not statistically representative. These limitations caution against overgeneralization but do not undermine the core, statistically significant relationships identified (Banseng et al., 2021; Waty et al., 2024).

The implications of this research are directly relevant for policymakers in Indonesia and similar economies. The findings suggest limitations in relying solely on EKC dynamics for environmental improvement. Instead, they advocate for proactive, integrated policies that: (1) Strengthen formal institutions by specifically targeting improvements in the environmental governance components of provincial SAKIP scores, particularly in permitting transparency and enforcement capacity; (2) Invest strategically in human capital through environmental education curricula and green skills training programs aligned with regional industrial profiles; and (3) Guide industrial and investment policy by creating differentiated regulatory incentives that encourage formalization of shadow economy activities while attracting FDI specifically in clean technology sectors through governance-linked tax benefits.

For future research, several avenues emerge. First, a deeper investigation into the components of "good governance" (e.g., corruption control, regulatory quality, public participation) would help identify the most impactful institutional levers. Second, applying this integrated framework in a comparative study across different emerging economies could test its generalizability (Hafnidar et al., 2021; Ramadhani et al., 2022). Finally, micro-level studies on the environmental behavior of firms in the formal versus informal sectors would provide ground-level insights to complement the macro-econometric findings presented here. This study has moved the understanding of environmental determinants forward by systematically integrating economic, social, and institutional variables and revealing their dynamic interdependencies, providing a more holistic foundation for the pursuit of sustainable development (Zainil et al., 2023; Hiltrimartin et al., 2024).

Conclusions

This study finds that environmental quality in Indonesia is shaped not only by economic growth but also by institutional strength. While an Environmental Kuznets Curve exists, its trajectory depends on governance quality. The shadow economy negatively affects the environment, whereas human development supports sustainability. A bidirectional relationship between economic growth and environmental quality indicates that environmental protection can contribute to long-term economic resilience. Therefore, sustainable development requires integrated policies that strengthen

institutions, reduce informal economic activity, and invest in human capital, offering a holistic framework applicable to other emerging economies.

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