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Local Government Expenditure and Environmental Quality in Indonesia: The Role of Spatial Dependence

Raisa Noor Maulida[1], Djoni Hartono[2], and Misdawita Misdawita[3]

[1]Badan Pusat Statistik Kota Banjarmasin, Indonesia
[2]Program Pascasarjana Ilmu Ekonomi, Fakultas Ekonomi dan Bisnis, Universitas Indonesia, Depok, Indonesia
[3]Program Studi Ekonomi Pembangunan, Fakultas Ekonomi dan Bisnis, Universitas Riau, Pekanbaru, Indonesia; e-mail: misdawita@lecturer.unri.ac.id

ABSTRAK

Kualitas lingkungan antardaerah di Indonesia masih tidak merata, sedangkan efektivitas belanja pemerintah daerah untuk fungsi lingkungan belum jelas karena dapat bergantung pada kondisi institusional dan keterkaitan antarwilayah. Penelitian ini bertujuan menganalisis pengaruh belanja pemerintah provinsi untuk fungsi lingkungan terhadap kualitas lingkungan di Indonesia dengan mempertimbangkan ketergantungan spasial serta peran pendapatan per kapita dan demokrasi daerah sebagai variabel pemoderasi. Penelitian ini menganalisis data panel 33 provinsi periode 2011-2019 menggunakan model STIRPAT dan regresi panel autoregresif spasial (SAR) dinamis dengan efek tetap. Efek marginal bersyarat belanja dihitung secara bersama dengan interaksi pendapatan per kapita dan demokrasi pada nilai median kedua moderator. Hasilnya menunjukkan bahwa efek marginal bersyarat tersebut kecil dan tidak signifikan pada Indeks Kualitas Lingkungan Hidup (IKLH), Indeks Kualitas Udara (IKU), maupun Indeks Kualitas Air (IKA). Di dalam efek gabungan ini, komponen dasar belanja bertanda negatif dan signifikan untuk IKLH dan IKU; interaksi belanja-demokrasi bertanda positif dan signifikan; sedangkan interaksi belanja-pendapatan per kapita tidak signifikan. Ketergantungan spasial terdeteksi pada ketiga indikator, tetapi efek tidak langsung atau limpahan spasial belanja umumnya lebih kecil daripada efek langsung; limpahan yang signifikan terutama muncul pada kualitas udara dalam jangka pendek. Temuan ini menunjukkan bahwa peningkatan anggaran saja belum cukup: kualitas pemanfaatan anggaran, kapasitas kelembagaan demokratis, dan koordinasi lintas wilayah menentukan apakah belanja lingkungan menghasilkan perbaikan yang terukur.

***Kata kunci*:** Belanja Pemerintah Daerah, Demokrasi, Ketergantungan Spasial, Kualitas Lingkungan Hidup, Regresi Spasial Dinamis

ABSTRACT

Environmental quality remains uneven across Indonesian provinces, while the effectiveness of subnational environmental expenditure is uncertain because it may depend on institutional conditions and cross-regional linkages. This study aims to assess how provincial environmental-function expenditure affects environmental quality in Indonesia while accounting for spatial dependence and the moderating roles of per capita income and regional democracy. This study examines a panel of 33 provinces from 2011 to 2019 using the STIRPAT framework and a dynamic spatial autoregressive (SAR) panel model with fixed effects. The conditional marginal effect of expenditure is jointly evaluated with its interactions with per capita income and democracy at the median values of both moderators. The combined conditional marginal effect is small and statistically insignificant for the environmental quality index (IKLH), air quality index (IKU), and water quality index (IKA). Within that combined effect, the baseline expenditure component is negative and significant for IKLH and IKU; the expenditure-democracy interaction is positive and significant; and the expenditure-income interaction is insignificant. Spatial dependence is detected for all three outcomes, but indirect expenditure effects are generally smaller than direct effects; a significant spillover appears mainly for short-run air quality. The results imply that larger budgets alone do not guarantee better environmental quality. Budget-use quality, democratic institutional capacity, and cross-regional coordination are essential for converting environmental expenditure into measurable outcomes.

***Keywords*:** Democracy, Environmental Quality, Local Government Spending, Spatial Dependence, Spatial Dynamic Regression

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1. INTRODUCTION

Environmental quality is a core public good and a continuing development concern in Indonesia. During the study period, poor air quality and widespread water pollution imposed health, productivity, and distributional costs (Damania et al., 2019; Majeed &

Ozturk, 2020). These problems are especially urgent in a decentralized archipelago because pollution crosses administrative borders while environmental services and enforcement are divided among levels of government. More recent evidence also identifies persistent water-security, wastewater-treatment, and institutional coordination gaps in Indonesia (World Bank, 2021).

Government expenditure is an important instrument for correcting environmental externalities and financing monitoring, waste management, pollution control, restoration, and environmental public goods (López et al., 2011; Halkos & Paizanos, 2013). Its effectiveness, however, depends not only on the amount allocated but also on expenditure composition, implementation capacity, accountability, and alignment with measurable environmental objectives. Contemporary green-budgeting practice therefore emphasizes the entire budget cycle - planning, allocation, execution, reporting, and oversight - rather than expenditure growth alone (OECD, 2024).

Indonesia's decentralization framework assigns provincial governments important environmental functions, including cross-district coordination, supervision, environmental information, and pollution control. Provincial budgets are therefore a relevant fiscal channel, although observed environmental quality is jointly produced by provincial, district/city, and central-government actions. This institutional overlap means that provincial expenditure should be interpreted as one component of environmental governance rather than its complete financing base.

International evidence on environmental expenditure is mixed. Government spending can improve environmental outcomes by financing protection and cleaner technology, but it can also stimulate output and consumption that generate pollution (López et al., 2011; Galinato & Islam, 2017; Moshiri & Daneshmand, 2020). Recent subnational studies likewise find heterogeneous local and spatial effects of environmental expenditure, indicating that sectoral structure, implementation quality, and interregional transmission matter (Fan et al., 2022; Fang et al., 2024; Sun et al., 2024).

Evidence for Indonesia is also inconclusive. Some studies report environmental improvements following local or deconcentrated expenditure (Orchidea et al., 2016; Oktavilia et al., 2021), whereas others find adverse or insignificant relationships (Ullah et al., 2020). These differences may arise because a single spending coefficient masks the conditions under which expenditure operates, including income, political institutions, pollutant type, and spatial dependence.

Per capita income may condition the expenditure-environment relationship. Wagner's Law links higher income to greater demand for public services, while the environmental Kuznets curve allows environmental pressure to vary nonlinearly with development (Panayotou, 1993). Higher-income provinces may have stronger fiscal and technical capacity, but scale effects from production and consumption can offset those gains. The expenditure-income interaction is therefore an empirical question rather than an assumed improvement channel.

Democratic institutions provide a second conditioning channel. Public access to information, political participation, legislative oversight, and accountability can make environmental budgets more responsive to citizens and more effectively implemented (Farzin & Bond, 2006; Galinato & Islam, 2017). Recent evidence similarly suggests that democratic institutions can strengthen environmental policy stringency, although effects depend on context (Mavisakalyan et al., 2023). Accordingly, this study tests whether democracy amplifies the association between provincial environmental expenditure and environmental quality.

Environmental outcomes may also be spatially dependent: airborne pollutants, river-basin pressures, economic activity, and regulatory responses can cross provincial boundaries. A non-spatial model may therefore misstate local and neighboring effects. At the same time, reverse causality is plausible because provinces facing worse environmental conditions may allocate more environmental expenditure. Temporal lags, province and year fixed effects, and a dynamic spatial specification can mitigate some of these concerns, but they do not eliminate endogeneity from time-varying omitted factors or non-random budget allocation.

Research gap and novelty. Existing Indonesian provincial studies generally do not integrate three features in one framework: dynamic adjustment in environmental quality, spatial dependence across an archipelagic setting, and interactions that make the expenditure effect conditional on income and democracy. This study contributes by estimating a dynamic SAR model, calculating the conditional marginal effect of expenditure rather than interpreting its main coefficient in isolation, and decomposing direct and indirect effects separately for aggregate environmental quality, air quality, and water quality. The democracy interaction is particularly important because it links fiscal inputs to the institutional conditions governing their use.

The analysis focuses on provincial expenditure because provinces coordinate environmental functions that cross district/city boundaries. It asks whether provincial environmental expenditure is associated with IKLH, IKU, and IKA; whether that association varies with per capita income and democracy; and how much of each effect is direct or transmitted as a spatial spillover. The results are interpreted as conditional associations within the stated model and data period, not as definitive causal effects.

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2. RESEARCH METHOD

This study uses a balanced panel of 33 Indonesian provinces, excluding North Kalimantan because a complete series was unavailable, for 2011-2019. Data were obtained from the Ministry of Environment and Forestry, Ministry of Finance, Investment Coordinating Board, and Statistics Indonesia. The dynamic specifications have fewer observations because one-period temporal and spatial-temporal lags are required. Variable definitions and sources are reported in Table 1.

The empirical approach uses the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model to describe environmental impacts influenced by population, community welfare, or income and technology (York et al., 2003). This study uses environmental impact indicators in the form of aggregate environmental quality index (IKLH) data for each province. Specifically, it uses the air quality index (IKU) and water quality index (IKA). There are three reasons for choosing these indicators. First, environmental quality is a pure public good. All economic actors can enjoy clean air and water without reducing consumption availability for other economic actors. Second, based on data accessibility and relevance, the environmental quality index is available for relevant inter-provincial comparisons within the same period. Third, this index provides information on aggregate measures of environmental quality that take into account the concentration of SO2 and NO2 emissions in the air and complete measurements of water pollution such as TS, DO, BOD, COD, and others (Almeida et al., 2017; Feng et al., 2018; Sumarni, 2019; Oktavilia et al., 2021).

The STIRPAT specification is extended with provincial environmental-function expenditure. The principal regressor, GE, is the annual environmental-function expenditure recorded in the provincial budget divided by provincial real GRDP per capita (2010 prices) and expressed as a percentage. This normalization measures spending intensity relative to average regional economic capacity and facilitates comparison across provinces of different economic scale; it is not the share of environmental expenditure in total APBD and does not measure expenditure composition or quality. GE is log-transformed and lagged one year because budget execution precedes the annual environmental-quality measurement and environmental responses are unlikely to be instantaneous.

$$\ln EQ_{itm} = \beta_0 + \beta_1\ lnGE_{it-1} + \beta_2\ (lnGE_{it-1} \times lnPDRBpc) + \beta_3\ (lnGE_{it-1} \times lnDemoc) + \boldsymbol{\gamma X}_{it} + \mu_i + \varsigma_t + \varepsilon_{it} \quad (1)$$

where i and t are the notations for province and year. β_1 to β_3 are the leading variable coefficients estimated using Ordinary Least Squares (OLS), with β_0 being a constant. ε_{it} is a random error, μ_i is a spatial coefficient or regional fixed effect that controls specific provincial conditions and does not vary over time. ς_t is a time-fixed effects indicator that controls a particular period and does not vary between provinces or regions.

EQ denotes three outcomes (m = 1, 2, 3): the environmental quality index (IKLH), air quality index (IKU), and water quality index (IKA). GE is the lagged provincial environmental expenditure intensity defined above; GRDPpc is real gross regional domestic product per capita; and Democ is the provincial democracy index. The control vector includes population density, manufacturing share, trade openness, foreign direct investment, road length, and mean years of schooling. Province and year fixed effects absorb time-invariant provincial characteristics and common annual shocks.

Table 1. Data and Data Sources

Indicators	Measurement	Data sources
Dependent variables:		
(i) Air Quality (IKU)	The air quality index is on a scale of 0-100. The greater the index value, the better the air quality	Indonesian Ministry of Environment and Forestry
(ii) Water Quality (IKA)	The water quality index is on a scale of 0-100. The greater the index value, the better the water quality	
(iii) Environmental Quality Life (IKLH)	The environmental quality index is on a scale of 0-100. The greater the index value, the better the environmental quality	
Independent Variables:		
Government Expenditure (GE)	Environmental-function expenditure recorded in the provincial APBD divided by real GRDP per capita (2010 prices), expressed as a percentage; log-transformed and lagged one year in the model	DJPK Ministry of Finance, BPS
Control Variables:		
GDP per capita (GRDPpc)	Gross Regional Domestic Product per Capita at Constant Prices 2010=100 (thousand rupiahs)	BPS
Democracy (Democ)	Indonesian democracy index for each province	
Population (dense)	Population density per area (people/km ^{2})	
Trading openness (shnx)	Share of the difference between exports and imports for each province to GRDP according to usage 2010=100	
Industrialization (si)	Share of manufacturing industry activity in business sector GRDP 2010=100	
Investment (FDI)	Realization of foreign investment (million USD)	BKPM, BPS
Transportation (street)	Road length by province (km)	BPS
Education (educ)	Average length of school (years)	

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In controlling for the diversity of economic development conditions in each province in Indonesia, the author tries to include economic income per capita (PDRBpc) variables based on the base year 2010=100. Then, this is approached with the concept of non-linear relationships in the form of the Kuznets Environmental Curve (EKC) by adding the PDRBpc squared variable.

Controlling for the effect of population on environmental quality uses the population density variable, which is the mid-year population based on the province's area (people/km^2). The greater the population density, the poorer the environmental quality (Huang, 2018). Increasing population density can reduce air pollution in China with mediators such as energy and public bus services (Chen *et al.*, 2020). The air quality index increases along with population density with an elasticity of 0.11-0.13 (Borck & Schrauth, 2021).

Furthermore, it controls the regional economic structure, especially manufacturing industry activity, with the variable share of manufacturing industry activity to Gross Regional Domestic Product (GRDP). Then, it includes the technology-level approach of each province with the variables of economic openness and realization of Foreign Direct Investment (FDI). According to the "Pollution Heaven" hypothesis, with economic openness, industrial companies with high pollution can migrate to countries or regions with lower environmental standards in the selection of FDI locations so that pollution in the FDI recipient country increases. Meanwhile, the "Pollution Halo" hypothesis suggests that FDI can reduce the pollution of the recipient country through the development of environmentally friendly technology and the spillover effect of management efficiency in the production system used by multinational companies adopting the research of Cheng *et al.* (2017) and Cheng *et al.* (2020). In addition, this study also controls for differences in transportation conditions between provinces through road length in kilometers. Longer road length indicates the number of motorized vehicles and inter-regional trade, which increases environmental pollution (Yang *et al*., 2015; Jiang *et al*., 2020). Finally, the present study includes human capital indicators through the average length of school time between provinces. A high level of education of the population can improve environmental quality (Farzin & Bond, 2006; Liu *et al.*, 2020).

Equation 1 includes interactions between expenditure and both moderators. In this log-log specification, the expenditure coefficient alone is not the overall marginal effect. The conditional marginal effect is $\frac{d\ln(EQ)}{d(\ln GE)} = \beta_1 + \beta_2 \ln(GRDP_{pc}) + \beta_3 \ln(Democ)$ evaluated at stated moderator values (Halkos & Paizanos, 2017). Thus, β_1 is the baseline expenditure component when the logged moderators equal zero, while β_2 and β_3 show how income and democracy change the expenditure slope. Table 6 evaluates the combined effect at the sample medians.

A spatial lag of the dependent variable is introduced because the substantive mechanism concerns diffusion and interaction in environmental outcomes across provinces, consistent with prior provincial spatial applications (Li & Zhou, 2019; Jiang et al., 2020; Ren & Matsumoto, 2020). This favors a SAR specification: a spatial error model would instead attribute dependence to correlated unobserved shocks, while a Spatial Durbin Model would additionally impose spatial lags for the explanatory variables. The SAR choice is therefore theory-driven and parsimonious for the available nine-year panel; it should not be read as evidence that every alternative spatial specification has been statistically rejected.

$$\ln EQ_{itm} = \rho \boldsymbol{W_{ij}} ln\, EQ_{itm} + \alpha_1 + \alpha_2\,(lnGE_{it-1} \times lnPDRBpc) + \alpha_3\,(lnGE_{it-1} \times lnDemoc) + \boldsymbol{\gamma X_{it}} + \mu_i + \varsigma_t + \varepsilon_{it} \quad (2)$$

Here, rho measures contemporaneous spatial dependence in environmental quality. W is a 33 x 33 inverse-distance matrix based on provincial centroids: $W_{ij} = \frac{1}{d_{ij}}\ 0 < d_{ij} <= 800\ km,\ W_{ij} = 0$ beyond 800 km, and $W_{ii} = 0$. The matrix is normalized so that its maximum eigenvalue equals one. An inverse-distance matrix is preferable to simple contiguity for an archipelago because island provinces may interact without sharing land borders. The 800 km threshold follows Indonesian spatial work (Chalil, 2020), retains plausible regional links, and avoids assigning meaningful weight to very distant provinces. It remains a modeling assumption rather than a physical boundary, so sensitivity to alternative thresholds is a limitation.

Reverse causality remains possible because governments may allocate more resources after environmental deterioration. The one-year expenditure lag establishes temporal ordering; province and year fixed effects control for time-invariant provincial heterogeneity and common shocks; and QML estimation accounts for the endogenous spatially lagged dependent variable under the maintained model assumptions. These features mitigate, but do not fully resolve, simultaneity, time-varying omitted variables, measurement error, or non-random budget allocation. Accordingly, the estimates are interpreted cautiously as conditional dynamic-spatial associations.

The dynamic specification combines a first temporal lag, a spatial-temporal lag, and the contemporaneous spatial lag of environmental quality. The temporal lag captures persistence, while the spatial-temporal term allows past environmental conditions in neighboring provinces to affect the current outcome. These terms follow the dynamic spatial-panel literature (Cheng et al., 2017; Cheng et al., 2020; Hao et al., 2021).

$$\ln EQ_{itm} = \tau lnEQ_{im,t-1} + \psi \boldsymbol{W} lnEQ_{im,t-1} + \rho \boldsymbol{W} ln\, EQ_{itm} + \theta_1\ lnGE_{it-1} + \theta_2\,(lnGE_{it-1} \times lnPDRBpc + \theta_3\,(lnGE_{it-1} \times lnDemoc) + \boldsymbol{\gamma X_{it}} + \mu_i + \varsigma_t + \varepsilon_{it} \quad (3)$$

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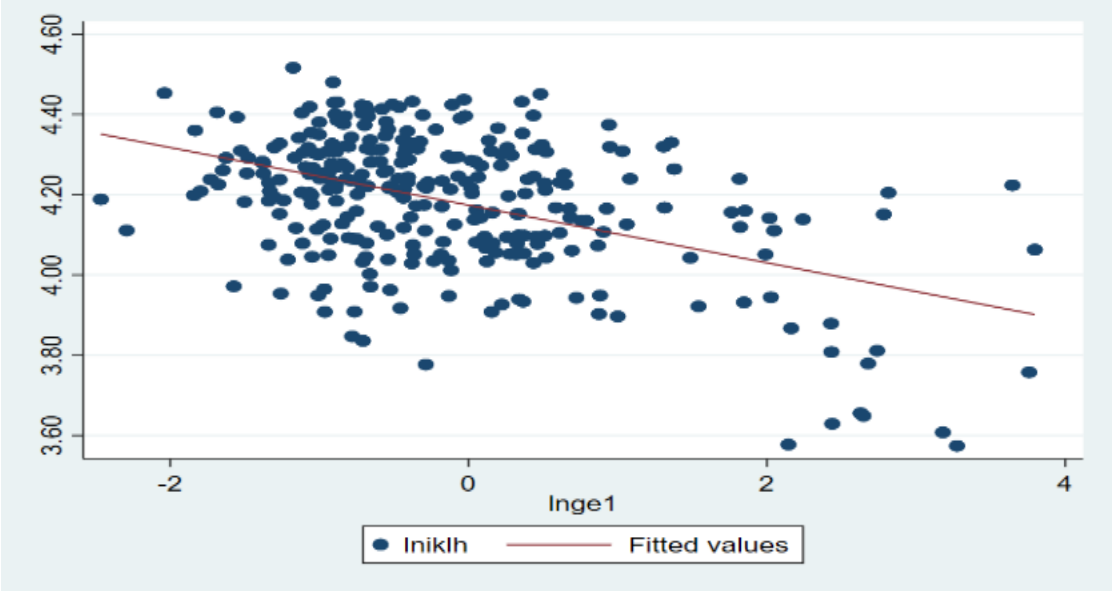
τ denotes persistence from the province's own lagged environmental quality, and ψ denotes the effect of neighboring provinces' lagged environmental quality. Equations 2 and 3 are estimated by Quasi Maximum Likelihood (QML) following Yu et al. (2008) and Belotti et al. (2017). Fixed effects are supported by Hausman tests. The need for a spatial specification is supported by Moran's I z-statistics and Friedman/Pesaran cross-sectional dependence tests (De Hoyos & Sarafidis, 2006); within the models actually estimated, the dynamic SAR is assessed using the significance of dynamic and spatial terms together with log-likelihood and AIC. Impact decomposition follows Elhorst (2014). Because SEM and SDM alternatives were not estimated, the manuscript describes SAR as the preferred theory-consistent specification rather than the uniquely optimal spatial model.

3. RESULTS AND DISCUSSION

3.1. Descriptive Analysis

Figure 1 provides a descriptive, unadjusted association between provincial environmental expenditure and IKLH for 2011-2019. The downward fitted line is not causal evidence because it does not control for province characteristics, time effects, income, democracy, or spatial dependence. The multivariate dynamic-spatial models below estimate the adjusted association. Table 2 summarizes the variables and shows substantial cross-provincial variation in both environmental outcomes and fiscal intensity.

There is a significant difference between the minimum and maximum values of the proportion of local government expenditure on environmental functions in the regional budget to GRDP per capita in Indonesia, with an average value of only 2.12%. This result is because most provincial governments only allocate regional expenditures for environmental functions with an average value of less than 1% of the total provincial budget for the 2011-2019 period (Orchidea et al., 2016). North Sumatra, Bangka Belitung, DKI Jakarta, and Gorontalo have an average proportion of provincial expenditure on environmental functions exceeding 1%. The low-budget allocation for environmental functions shows that regional budgeting policies have not prioritized environmental protection issues. Unfortunately, this is not in accordance with the direction of national development planning, which places environmental issues as one of the strategic issues.



Source: KLHK and DJPK Kemenkeu, processed

Figure 1. Diagram of Local Government Expenditure on Environmental Function and Environmental Quality Index

Table 2. Summary of Research Variable Statistics

Variables	Unit	Obs	*Mean*	Std. Deviation	Min.	Max.
IKLH	indeks	297	66,58	10,42	35,66	91,5
IKU	index	297	85,09	9,75	41,51	97,74
IKA	indeks	297	58,86	14,43	20,19	89,09
GE	*Environmental spending intensity (%)*	297	2,12	5,21	0,08	44,52
PDRBpc	IDR million	297	36,83	28,88	9,68	174,14
Democ	indeks	297	70,59	6,98	52,61	88,29
Dense	persons/km2	297	812,33	2.782,62	2,47	15.900,00
FDI	USD million	297	832,33	1.250,81	0,2	7.124,90
Shnx	*Share PDRB (%)*	297	-0,01	20,58	-57,46	56,47
SI	*Share PDRB (%)*	297	15,51	10,82	1,23	43,9
Road	km	297	16.770,05	16.767,52	3.183,00	218.241,00
Educ	years	297	8,04	1	5,6	11,06

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3.2. Empirical Results

Table 3 reports diagnostics for spatial and cross-sectional dependence. The entries in the Moran column are standardized Moran's I z-statistics, not raw Moran's I coefficients. Their significant magnitudes, together with the Friedman and Pesaran results, indicate that independence across provinces is not a tenable assumption for IKLH, IKU, and IKA. The sign of a z-statistic should not be interpreted as the size of a spatial spillover; spillover magnitudes are obtained from the model's impact decomposition.

Table 4 compares non-spatial, static spatial, and dynamic spatial estimates, with provincial expenditure lagged one year. Interaction terms are retained because the effect of expenditure is hypothesized to vary with income and democracy. Once interactions are included, the coefficient on ln(GE) cannot be interpreted by itself; the relevant expenditure effect is the conditional marginal effect computed from the main and interaction terms.

The dynamic SAR with interactions is the preferred reported specification because it represents the hypothesized outcome diffusion, captures temporal persistence and spatial-temporal dependence, includes province and year fixed effects, and improves fit relative to the non-spatial and static SAR models shown. These features reduce several sources of misspecification, but they do not establish exogeneity of expenditure. The results should therefore be read as robust conditional associations under the maintained SAR structure, not as definitive causal estimates.

The coefficient on ln(GE) in the interaction model is a baseline component, not a stand-alone marginal effect. It is negative and statistically significant for IKLH and IKU, but it corresponds to $ln(GRDPpc) = ln(Democ) = 0$, a value outside the substantively relevant sample range. The meaningful interpretation therefore comes from combining this coefficient with both interaction terms. The negative baseline component is consistent with a countervailing mechanism in which expenditure-related activity and consumption can generate pollution when environmental programs are small, poorly targeted, or slow to produce results (Galinato & Islam, 2017).

The expenditure-income interaction is positive but statistically insignificant in the dynamic IKLH model. Thus, the data does not show that higher provincial income systematically strengthens the environmental return to expenditure. A plausible explanation is that greater fiscal and technical capacity is offset by the scale of production and consumption, and that aggregate GRDP per capita does not distinguish cleaner services from pollution-intensive manufacturing. This non-result should not be interpreted as evidence of no role for economic structure.

Table 3. Spatial and Cross-Sectional Dependence Test Results

Variables	Moran's I z-statistic	Friedman	Pesaran	
			Statistics	Absolute
lnIKLH	15,955***	77,737***	20,000***	0,39
lnIKU	5,839***	41,18	9,748***	0,35
lnIKA	-3,888***	78,190***	19,599***	0,454

*significance: *p < 0.10; **p < 0,05; ***p < 0.01. Note: The Moran column reports standardized z-statistics rather than raw Moran's I coefficients. Asterisks indicate significance (* p < 0.10; ** p < 0.05; *** p < 0.01).*

Table 4. Model Estimation of the Environmental Quality Index in Indonesia, 2011-2019

Variables	Static Spatial Panel				Dynamic Spatial Panel			
	IKLH1	IKLH2	IKU	IKA	IKLH1	IKLH2	IKU	IKA
ττ(dynamic factor)					0,3409***	0,3192***	0,4785***	0,3340***
ρρ(spatial factor)	0,3205***	0,3000***	0,3171***	0,5629***	0,3357***	0,2868**	-0,2523*	0,5327***
ln $(GE)_{t-1}$	0,0052	-0,5072**	-1,5315***	0,7358	0,0029	-0,4095*	-1,0443***	0,5375
*ln$(GE)_{t-1}$*lnPDRBpc*		0,011	0,0617***	-0,0015		0,0027	0,0146	0,0062
*ln$(GE)_{t-1}$*lnDemoc*		0,0940**	0,2128***	-0,1645		0,0905**	0,2109***	-0,1359
lnPDRBpc	-2,5977***	-2,3552***	-2,3763***	-4,2187	-2,5769***	-2,4125**	-2,0513**	-5,9252*
lnPDRBpc²	0,1064***	0,0949***	0,1037***	0,1772	0,1083**	0,0994**	0,0865*	0,2721*
ln Democ	0,0348	0,049	0,1807***	-0,0226	0,0959	0,1021	0,2072***	-0,0135
ln dense	0,0033	0,0033	-0,0028	0,0048	-0,0652	-0,0529	-0,1416*	-0,1253
ln FDI	0,0016	0,0037	0,0016	0,0315	0,0024	0,0046	0,0104	0,0142
shnx	0,0004	0,0006	-0,0004	-0,0007	0,001	0,0012	-0,0005	0
si	0,0027	0,0028	0,0029	-0,0046	0,0032	0,0038	0,0081**	0,0044
ln educ	0,6897*	0,7059*	1,0307***	1,9887**	0,8467**	0,8129**	0,1177	1,7578*
ln jln	-0,0277*	-0,0273*	-0,0225	-0,0328	-0,0271*	-0,0271*	0,0057	-0,0777
*ψ ψ (W*dependent)*					-0,2226*	-0,1887	0,4610***	-0,5737***
N	264	264	264	264	231	231	231	231
r2	0,521	0,5139	0,2722	0,0644	0,5341	0,5289	0,1361	0,0693
Log Likelihood	411,7366	415,1833	365,1202	57,7883	359,2489	362,244	352,2089	50,4087
AIC	-759,473	-754,367	-654,24	-39,5766	-610,498	-596,488	-576,418	23,1827
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hausman	55,26***	60,97***	215,08***	107,45***				

*Significance: * p < 0.10; ** p < 0.05; *** p < 0.01*

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The expenditure-democracy interaction is positive and statistically significant for IKLH and IKU. In substantive terms, stronger democratic conditions make the expenditure slope more favorable, consistent with mechanisms of transparency, citizen voice, legislative scrutiny, and enforcement. This institutional interaction - rather than unconditional spending coefficient - is the study's clearest contribution. It also accords with recent evidence that democratic institutions can strengthen environmental policy responsiveness (Mavisakalyan et al., 2023).

Spatial dependence differs across outcomes. In the preferred dynamic models, the contemporaneous spatial coefficient is positive for IKLH and IKA but negative for IKU, while the spatial-temporal term is positive for IKU and negative for IKA. These coefficients describe dependence on the outcomes and should not be equated with the indirect effect of expenditure. The latter is calculated from the spatial multiplier and reported in Table 5. This distinction explains why a significant spatial parameter does not automatically imply a significant spending spillover.

For the control variables, GRDP per capita and its square indicate a U-shaped association with IKLH in the reported specification. Education is positively associated with IKLH, while road length is negatively associated. These estimates are conditional on the spatial and dynamic terms and should be interpreted within the sample period rather than as universal turning-point relationships.

The three outcomes reveal different fiscal pathways. For IKLH, the negative baseline expenditure component is offset by the positive democracy interaction, producing a small, insignificant combined conditional marginal effect at median moderator values. IKU shows the same countervailing structure and the clearest short-run spatial transmission. By contrast, neither the baseline nor interaction components are significant for IKA. Because IKLH is a composite index, its aggregate result can conceal these offsetting air- and water-quality responses.

Regarding the control variables, a U-shaped non-linear relationship exists between per capita income and air and water quality in Indonesia. This result can be seen from the regression coefficients for the GRDP and quadratic GRDP variables, which are significant at an alpha of 10%. This finding is in accordance with Sumarni (2019). Furthermore, population density has a negative and significant relationship with air quality, which aligns with Huang (2018). Meanwhile, the level of democracy has a positive and significant effect, as found by Farzin & Bond (2006) and Arvin & Lew (2011). Finally, in the water quality index model, a positive and significant relationship was found between average years of schooling and water quality, in line with Farzin & Bond (2006). The interpretation of the regression coefficients needs to consider the spatial dependence in direct, indirect, and total effects in the short and long terms.

Table 5 decomposes each spending-related coefficient component into direct, indirect, and total impacts; it does not report the complete conditional marginal effect of expenditure. For IKLH, the baseline spending component has a negative significant direct impact in both the long and short run, while its indirect impact is insignificant. The negative total baseline component is therefore driven mainly by the province's own response rather than by neighboring provinces.

For IKU, the baseline spending component has a negative significant direct impact. Its short-run indirect impact is positive and significant, suggesting that expenditure changes in nearby provinces can improve local air quality through regional transmission, even though the short-run total baseline component remains negative. The long-run total baseline component is not significant. This pattern reinforces the need to distinguish local impacts from spillovers and short-run from long-run responses.

The democracy interaction produces positive significant direct and total components for IKLH. This means that stronger local democratic conditions shift the local expenditure association in a more favorable direction; the corresponding neighboring-democracy component is not significant. These component estimates describe how democracy modifies the expenditure slope and are combined with the other terms in Table 6.

Table 5. Spatial Decomposition of Spending-Related Coefficient Components for Environmental, Air, and Water Quality

Variables		Long term			Short term		
		IKLH	IKU	IKA	IKLH	IKU	IKA
		-1	-2	-3	-4	-5	-6
Direct	$ln\ (GE)_{t-1}$	-0,5685*	-2,0585**	0,9392	-0,3887*	-1,0247***	0,6475
	$ln(GE)_{t-1}$*lnPDRBpc	0,0027	0,0277	0,0043	0,0018	0,0136	0,003
	$ln(GE)_{t-1}$*lnDemoc	0,1283**	0,4181***	-0,2229	0,0877**	0,2085***	-0,1538
Indirect	$ln\ (GE)_{t-1}$	-0,0633	-1,644	-0,0326	-0,0942	0,1414*	0,4151
	$ln(GE)_{t-1}$*lnPDRBpc	0,0006	0,0266	0,0002	0,0006	-0,0018	0,0025
	$ln(GE)_{t-1}$*lnDemoc	0,0135	0,3236	0,0069	0,0208	-0,0289*	-0,1
Total	$ln\ (GE)_{t-1}$	-0,6318*	-3,7025	0,9067	-0,4829*	-0,8834***	1,0626
	$ln(GE)_{t-1}$*lnPDRBpc	0,0033	0,0543	0,0045	0,0025	0,0118	0,0055
	$ln(GE)_{t-1}$*lnDemoc	0,1418**	0,7417	-0,216	0,1085**	0,1796***	-0,2538

*Significance: *p < 0.10; **p < 0.05; ***p < 0.01. Note: Each model term is decomposed into direct, indirect (spillover), and total impacts. These component-specific estimates are not the complete marginal effect of expenditure when interactions are present.*

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For IKU, the democracy interaction is positive and significant for the direct long- and short-run components and for the short-run total component, but not for the long-run total component. The income interaction remains insignificant. For IKA, none of the direct, indirect, or total spending-related components is statistically significant. Hence, the evidence for institutional amplification is concentrated in aggregate environmental quality and air quality, not water quality.

Across outcomes, direct impacts are generally larger than indirect impacts. The clearest expenditure spillover is the positive short-run indirect component for air quality, which is consistent with the mobility of air pollutants and coordinated regulation. This does not imply that every spatial coefficient or every environmental outcome has a positive spillover.

Table 6 combines the baseline expenditure term with the income and democracy interaction contributions to obtain the conditional marginal effect at the sample medians: GRDP per capita of IDR 28.04 million and a democracy index of approximately 70.94. This is the appropriate expenditure effect in an interaction model. The three columns are components of one calculation and should not be interpreted as independent overall effects.

At the median moderator values, the combined conditional marginal effect is close to zero and statistically insignificant for IKLH, IKU, and IKA, despite significant baseline and democracy-interaction components for IKLH and IKU. The correct overall conclusion is therefore not that expenditure generally improves environmental quality, but that its association is conditional and that stronger democracy offsets an otherwise unfavorable baseline component. This pattern is consistent with the view that expenditure effectiveness depends on institutional quality and budget implementation (OECD, 2024).

The placebo robustness check replaces environmental-function expenditure with social-protection expenditure. The alternative expenditure measure is not significantly associated with IKLH, IKU, or IKA through either its baseline or interaction components. This supports the environmental specificity of the reported pattern, although it does not eliminate endogeneity in the environmental-expenditure model.

The analysis uses provincial expenditure as the observed fiscal input. Environmental quality, however, is jointly affected by district/city budgets, central transfers, private compliance, and program execution. The omission of district/city environmental expenditure is therefore a substantive limitation and is especially important for water and sanitation services that are often implemented locally.

The significant temporal and spatial-temporal terms indicate persistence and cross-provincial dynamics in environmental quality. Pollution accumulated in previous years can remain even when current expenditure changes, so annual budget adjustments may not generate immediate index improvements. This persistence supports multi-year programming and outcome monitoring rather than one-year expenditure targets.

The negative baseline spending component should be interpreted as a signal about expenditure effectiveness, not as proof that environmental budgets are intrinsically harmful. Provinces differ in personnel, capital, monitoring, enforcement, and restoration allocations, while aggregate spending data do not reveal whether funds reached high-impact activities. Recent spatial evidence also shows that environmental-expenditure effects vary across regions and neighboring jurisdictions (Fan et al., 2022; Sun et al., 2024).

A second explanation is incomplete fiscal coverage. Provincial governments coordinate and supervise environmental functions, but district/city governments and central transfers finance many facilities and services. If provincial expenditure rises in response to deterioration while complementary local investment is missing, the estimated baseline component can remain negative. This reinforces the need to assess the full intergovernmental financing chain.

Table 6. Conditional Marginal Effect of Local Government Expenditure at Median Moderator Values

Effects		Baseline Term	Income Interaction: Gross Regional Domestic Product per Capita	Democracy Interaction	Conditional Marginal Effect
IKLH	*Coef.*	-0,4095*	0,0276	0,3857**	0,0039
	Long Run	-0,6318*	0,0338	0,6044**	0,0063
	Short Run	-0,4829*	0,0256	0,4624**	0,0051
IKU	*Coef.*	-1,0443***	0,1495	0,8989***	0,0041
	Long Run	-3,7025	0,556	3,1611	0,0147
	Short Run	-0,8834***	0,1208	0,7654***	0,0029
IKA	*Coef.*	0,5375	0,0635	-0,5792	0,0218
	Long Run	0,9067	0,0461	-0,9206	0,0322
	Short Run	1,0626	0,0563	-1,0817	0,0372

*Significance: *p < 0.10; **p < 0.05; ***p < 0.01. Note: The conditional marginal effect combines the baseline term and both interaction contributions at median GRDP per capita (IDR 28.04 million) and democracy (approximately 70.94). Asterisks attached to components denote their individual significance; the unstarred combined effects are not statistically significant.*

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Table 7. Robustness Checks QML Estimation Results

Variables	Model 1			Model 2		
	IKLH	IKU	IKA	IKLH	IKU	IKA
	-1	-2	-3	-4	-5	-6
ln (GE)$_{t-1}$	-0,4095*	-1,0443***	0,5375			
*ln(GE)$_{t-1}$*lnPDRBpc*	0,0027	0,0146	0,062			
*ln(GE) $_{t-1}$*lnDemoc*	0,0905**	0,2109***	-0,1359			
ln (SP)$_{t-1}$				-0,386	-0,0698	-1,1093
*ln(SP)$_{t-1}$*lnPDRBpc*				0,0202	-0,0021	0,0836
*ln(SP) $_{t-1}$*lnDemoc*				0,0456	0,0219	0,0687
lnPDRBpc	Yes	Yes	Yes	Yes	Yes	Yes
lnPDRBpc^2	Yes	Yes	Yes	Yes	Yes	Yes
ln dense	Yes	Yes	Yes	Yes	Yes	Yes
ln FDI	Yes	Yes	Yes	Yes	Yes	Yes
shnx	Yes	Yes	Yes	Yes	Yes	Yes
si	Yes	Yes	Yes	Yes	Yes	Yes
ln educ	Yes	Yes	Yes	Yes	Yes	Yes
ln jln	Yes	Yes	Yes	Yes	Yes	Yes
ln Democ	Yes	Yes	Yes	Yes	Yes	Yes
ρρ(spatial factor)	0,287**	-0,253*	0,5327***	0,325***	0,249**	0,548***
ττ(dynamic factor)	0,319***	0,478***	0,3340***	0,319***	0,502***	0,326***
*ψ ψ (W*dependent)*	-0,188	0,461***	-0,524***	-0,1985	0,021	-0,556***
N	231	231	231	231	231	231
r^2	0,529	0,136	0,069	0,53	0,353	0,068
Loglikelihood	362,244	352,209	50,409	361,596	319,073	50,972
AIC	-596,488	-576,418	-23,183	-691,191	-606,145	-69,945
Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

*Significance: *p < 0.10; **p < 0.05; ***p < 0.01*

Budget quality is therefore as important as budget size. Environmental tagging, program-level performance indicators, cost-effectiveness appraisal, execution monitoring, and public reporting can help distinguish personnel or administrative expenditure from investments that directly reduce pollution. Green-budgeting evidence emphasizes that institutional arrangements, appraisal tools, transparency, and oversight are necessary to connect allocations with outcomes (OECD, 2024).

The positive democracy interaction provides the central institutional interpretation. Civil liberties, public access to environmental information, legislative review, and accountable enforcement can improve project selection and reduce leakage or symbolic spending. The finding does not mean democracy automatically improves every outcome; rather, within this sample it makes the environmental expenditure slope more favorable for IKLH and IKU.

The insignificant income interaction suggests that economic capacity alone is insufficient. Higher-income provinces may finance better services, but they can also generate more industrial output, transport, and consumption. Future work should separate sectoral GRDP, own-source revenue, and expenditure composition to distinguish fiscal capacity from pollution-intensive scale effects.

The absence of a significant IKA effect is a crucial result. Water pollution is often basin-specific, cumulative, and driven by domestic wastewater, agriculture, industry, and upstream-downstream linkages that do not align with provincial boundaries. Provincial programs may emphasize monitoring and regulation, while treatment infrastructure and sanitation services are frequently implemented by district/city governments. Indonesia's water-security assessment also identifies fragmented responsibilities, underinvestment, and inadequate wastewater treatment (World Bank, 2021). Measurement frequency, program lags longer than one year, and the omission of district/city spending may therefore weaken the observed provincial expenditure-IKA relationship. These mechanisms are plausible explanations, not directly tested channels.

For policy, provinces should prioritize program portfolios that can be linked to measurable outputs and outcomes: wastewater collection and treatment, pollution-load reduction, laboratory and monitoring coverage, enforcement follow-up, waste-management infrastructure, and ecosystem restoration. Budget increases should be accompanied by expenditure review, transparent performance reporting, and coordination with district/city governments.

Spatial coordination should also match the environmental pathway. Air-quality policy requires joint monitoring and emission control across neighboring provinces, whereas water-quality policy should be organized around river basins and upstream-downstream responsibilities. Because the model uses a common distance matrix, future research should test pollutant-specific connectivity matrices based on prevailing winds, river networks, trade flows, or economic linkages.

4. CONCLUSION

Using a dynamic SAR panel for 33 provinces in 2011-2019, this study finds that the combined conditional marginal effect of provincial environmental expenditure is small and statistically insignificant for IKLH, IKU, and IKA at median income and democracy. The underlying components differ: the baseline expenditure term is negative and

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significant for IKLH and IKU, the expenditure-democracy interaction is positive and significant, and the expenditure-income interaction is insignificant. Direct effects generally exceed spillovers, with the clearest significant indirect effect occurring for short-run air quality. No spending-related component is significant for water quality.

Policy should therefore focus on the quality of budget utilization rather than budget expansion alone. Provinces need stronger program targeting, expenditure composition review, outcome-based monitoring, transparency, legislative and public oversight, and intergovernmental coordination. Democratic institutional capacity is particularly important for converting fiscal allocations into environmental improvements, while water-quality policy requires closer alignment between provincial coordination, district/city service delivery, and river-basin management.

The findings are limited by the exclusion of district/city expenditure, the 2011-2019 observation period, the aggregate expenditure measure, and reliance on one inverse-distance matrix with an 800 km threshold. The dynamic SAR and fixed effects mitigate some sources of bias but do not eliminate reverse causality or time-varying omitted variables, and SEM/SDM alternatives were not estimated. Future research should use newer and more disaggregated fiscal data, test alternative spatial matrices and spatial-model specifications, examine expenditure composition, and employ stronger identification strategies where valid instruments or policy discontinuities are available.

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