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The Role of Government Spending in Water Pollution Control

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Abstract

The global clean water crisis is an urgent challenge. Althought the water stress level in most provinces in Indonesia remains low, the water quality index does not reach good status. Water quality index calculated through pollution index of surface water. This study examines how environmental protection spending by local governments defined as the combined spending of provincial and regency/municipality governments within each province affects the water quality index in Indonesian provinces, and compare it with central government spending and non-government spending. Government spending has three effects on water pollution: scale, composition, and technique effects. These three effects are expected to follow a quadratic pattern. Using provincial panel data from 2017 – 2022, this study estimates these with fixed effect model. Initially, the estimation uses quadratic specification on local government spending, but likelihood ratio test shows that the quadratic term does not improve model fit, so the analysis proceeds with the linear specification. The results show that local government spending and non-government spending increase the water quality index, but central government spending is not significant due to its long-term effects. Non-government spending is more effective than government spending. Therefore, the local government should enforce regulations on businesses/ local-owned enterprises that use surface water to make efforts to maintain water sources. In addition, the local government needs to consider the development of a localized wastewater management system but still considering the necessary technical matters.

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INTRODUCTION

The global water crisis is an urgent challenge that needs to be addressed. The Earth's water composition consists of 97% seawater and only 3% freshwater. Of the 3% freshwater, 70 % is stored in glaciers, 29% is groundwater, and only 1% is surface water. Although the amount of surface water is smaller than that of other water sources, it is the most accessible freshwater source. This condition has contributed to the global water crisis. According to the United Nations 2023 Water Conference, around two to three billion people worldwide experience a lack of clean and safe water (UNESCO, 2024).

The World Resources Institute has developed several indicators related to water risk, including water stress. Water stress is defined as the ratio of water demand to the availability of groundwater and surface water. This ratio can indicate a clean water crisis. Indonesia's national average for water stress is medium–high (20–40%), while Malaysia is low–medium (10–20%) and Singapore is low (less than 10%). However, at the provincial level, most provinces in Indonesia are classified as having low water stress (World Resources Institute, 2024).

In terms of quality, no province in Indonesia has achieved a good level of surface water quality (above 70). As of 2022, eight provinces in Indonesia were still classified as having poor water quality (below 50), while the rest were categorized as moderate (Directorate General of Pollution and Environmental Damage Control, 2023). In other words, although the quantity of water in several provinces in Indonesia may be sufficient, its quality is not necessarily adequate.

Indonesia's Water Quality Index (WQI) is a composite index of surface water quality parameters within a specific area at a given time. This index is calculated using the pollution index conversion method, which converts the composite value of ten parameters measured at each monitoring point into a quality standard score. The method used in Indonesia combines the STORET system and the Pollution Index, both adopted from the United States Environmental Protection Agency (EPA) system developed in the 1960s (Wong et al., 2020).

Poor water quality is primarily caused by water pollution. High levels of pollution in surface water may result from population growth or economic growth (Dietz & Rosa, 1994; Ehrlich & Holdren, 1971; Liang et al., 2020; Yuan, 2019). Water pollution can also be exacerbated by climate change (Mahmoodi et al., 2021; Qiu et al., 2023). Previous studies have found a nonlinear relation between economic growth and pollution. Previous studies found a nonlinear relationship between economic growth and pollution. When the economy becomes more developed, economic growth may be accompanied by the adoption of cleaner technologies, which can reduce water pollution (Cui et al., 2021; Fan et al., 2022; Grossman & Krueger, 1995; Idris & Sari, 2022; Lee et al., 2010; Zhang et al., 2017). However, the transition that changes the direction of these impacts does not occur automatically and requires proactive policies (Grossman & Krueger, 1995).

The inverted U-shaped relationship between economic growth and pollution is commonly referred to as the Environmental Kuznets Curve (EKC). The term is derived from Kuznets' (1965) theory of the relationship between economic growth and inequality. The EKC follows a pattern analogous to the Kuznets curve, which is upward-sloping before the turning point and downward-sloping afterward. The EKC suggests that at low levels of economic development, economic growth leads to industrialization, which is accompanied by increasing levels of pollutants from industrial activities. However, as the economy becomes more developed, economic growth tends to shift toward the service sector and cleaner industries, as greater technological adoption reduces pollution levels. Specifically regarding water pollution, Grossman and Krueger (1995) cite World Bank findings indicating that in high-income countries, access to clean water and sanitation increases. This improvement reduces water pollution levels.

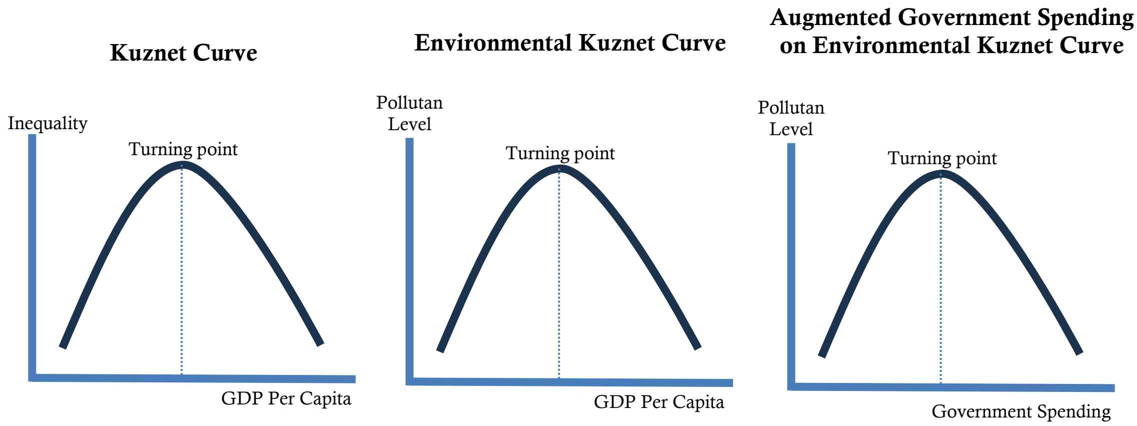

Figure 1. Kuznet Curve, Environmental Kuznet Curve, Augmented EKC
Source: Grossman and Krueger (1995), López et al. (2011)

Therefore, the government plays an important role in this process. Without adequate regulation and supervision, individuals and organizations may access water resources without responsibility, potentially ignoring environmental externalities. The mechanism by which government spending affects pollution is explained in the conceptual model of López et al. (2011). In their framework, López et al. (2011) divide total government spending into public goods spending and private goods spending, referring to the earlier work of López & Galinato (2007).

Public goods spending is defined as expenditure that reduces the impact of market failures and complements private sector inputs. Examples include spending on education, health, research, environmental protection, and other public services. In contrast, private goods spending refers to expenditure that is substitutable for private sector capital, such as subsidies for agricultural tools and machinery. Government spending on public goods affects all sectors, including both more polluting sectors (dirty sectors such as agriculture, mining, and industry) and less polluting sectors (clean sectors such as services). Meanwhile, private goods spending primarily affects more polluting sectors (López et al., 2011).

There are three main effects of increased government spending on public goods regarding pollution. First is the scale effect, which refers to an increase in pollutant levels resulting from the expansion of the economy. Government spending on public goods increases the output of all sectors, including dirty sectors. Higher output in these sectors raises the demand for production inputs that may pollute the environment (dirty inputs). Second is the composition effect, which represents a reduction in pollutant levels as government spending on public goods stimulates output in cleaner sectors, thereby reducing the relative share of output in dirty sectors. López et al. (2011) assume that the elasticity of output with respect to government spending is greater in clean sectors than in dirty sectors. Third is the technique effect, which reflects a reduction in pollutant levels due to technological changes in the production process. Increased government spending on public goods enhances human capital and encourages the substitution of dirty inputs with cleaner production methods. Workers with higher human capital are more likely to adopt cleaner production techniques that reduce the use of polluting inputs (López et al., 2011).

From these three mechanisms, it can be concluded that government spending on public goods influences pollution by altering output. When linked to the Environmental Kuznets Curve (EKC), government spending on public goods may exhibit an inverted U-shaped relationship with pollution, as illustrated in Figure 1. The scale effect tends to dominate in the phase before the turning point, while the composition and technique effects become more prominent after it. A quadratic relationship between government spending on public goods and water pollution levels has been identified in China (Yang et al., 2021).

In controlling water pollution, the Government of Indonesia distributes responsibilities across different levels of government. Law Number 23 of 2014 stipulates that the prevention, mitigation, and restoration of pollution in surface waters located entirely within a regency or municipality fall under the authority of the regency or municipality. For water bodies that cross regency or municipal boundaries, authority lies with the provincial government, while responsibility for inter-provincial or transboundary waters rests with the central government. These efforts also involve non-governmental actors. Government Regulation Number 22 of 2021 emphasizes that any business or activity that pollutes surface water is responsible for undertaking mitigation and restoration measures.

In Indonesia, the Water Quality Index (WQI) tends to increase, but the average growth rate is very small, at 0.29%. Consequently, the national WQI did not reach its target by 2022. The WQI in 252 regencies/municipalities declined in 2022 (Directorate General of Pollution and Environmental Damage Control, 2023). This trend coincides with a 16% decrease in total local government expenditure on environmental protection in 2022 (Directorate General of Fiscal Balance, 2024). There appears to be a similar trend between aggregate local government expenditure on environmental protection in a province and that province's WQI. In addition to the national aggregate pattern, several provinces also experienced similar trends. This may indicate that efforts to maintain water quality depend partly on local government spending.

Nevertheless, the contributions of central government spending and the non-governmental sector should not be overlooked. River basins within a province may also include strategic and interprovincial river basins, which fall under the authority of the central government. These two categories account for 58% of the total river basins. On the other hand, costs internalized by the non-governmental sector can directly influence surface water quality. Therefore, although local government spending has consistently accounted for the majority share (around 90% during 2017–2022), expenditures from smaller sectors—such as the central government and non-governmental sectors—may still have a significant impact on improving water quality.

The contribution of the non-governmental sector has been demonstrated in several previous studies. Cui et al. (2021) examined private investment in environmental management and found that it led to a greater reduction in water pollution than government spending. López et al. (2011) found that the proportion of investment relative to GDP could reduce water pollution. Yang et al. (2021) used credit allocation to examine the role of business entities. When the proportion of credit allocated to private enterprises exceeds that allocated to local-owned enterprises, pollutant levels increase due to weaker regulatory enforcement, as private enterprises interact more directly with local governments (Yang et al., 2021). This situation implies that efforts by local-owned enterprises may help reduce pollutant levels, although this was not the primary focus of Yang et al. (2021). This issue is particularly relevant in Indonesia, where the majority of clean water companies are regionally owned enterprises.

Other factors also influence water pollution. First, economic activity is often proxied using industrial structure variables (Yang et al., 2021; Zeraibi et al., 2021). However, this relates closely to the composition effect. A decline in the proportion of dirty sectors, including industry, reduces the use of polluting inputs and ultimately lowers water pollution. Consequently, this variable cannot be included in the research model due to the potential for bad control, since government spending—as used in this study—may influence industrial structure. Therefore, to obtain a more appropriate control variable (reducing selection bias) while representing economic activity affecting water pollution, the number of industries is used.

Second, domestic activities may also affect water pollution. In previous studies, domestic activities were proxied by population density, urbanization rate, and electricity consumption. However, population density and electricity consumption were not found to influence water pollution significantly (Cui et al., 2021). Meanwhile, a higher proportion of urban residents relative to rural residents was found to have a negative effect on water pollution, although Yang et al. (2021) did not explain this anomaly. One possible explanation is the lack of wastewater treatment facilities in rural areas compared with urban areas. Urban populations are more likely to have access to wastewater management infrastructure, while rural populations have less access.

Furthermore, Indonesia's urbanization rate is not published annually, making it difficult to observe year-to-year variations. Therefore, a household-based approach, such as using the number of households in a province, may provide a useful alternative. This variable is chosen to reduce potential selection bias related to spending on domestic wastewater management while simultaneously capturing factors influencing water pollution. Government decisions to develop wastewater management systems often depend on the number of household connections.

Third, regarding climate change, the most frequently examined variable is rainfall. While extreme increases in rainfall can cause flooding and landslides that affect water quality, studies by Mahmoodi et al. (2021) and Qiu et al. (2023) found that extremely low rainfall can also worsen water quality by reducing water flow and increasing pollutant concentrations.

Therefore, this study aims to analyze the impact of aggregate provincial and regency/municipal government spending on environmental protection on the provincial water quality index in Indonesia, and to compare it with the impact of central government spending and non-governmental sector spending. This research is expected to contribute to the evaluation of policies aimed at improving regional water quality in Indonesia. Previous studies in Indonesia have mostly examined environmental quality from a broader perspective (Nihayah & Diastuti, 2023; Oktavilia et al., 2021).

This study contributes to the literature in three main ways. First, it provides empirical evidence on the impact of government spending on water pollution, a topic that has received far less attention than air pollution, particularly outside the context of China (e.g., Abbass et al., 2022; Cui et al., 2021; Fan et al., 2022; Huynh, 2020). Second, building on the conceptual framework of López et al. (2011), this study examines all three effects—scale, composition, and technique—rather than focusing solely on the scale effect, as in most previous studies (Adewuyi, 2016; Halkos & Paizanos, 2013; Muyibi et al., 2008; Zeraibi et al., 2021; Zhang et al., 2017). Empirically, in the quadratic specification, the linear term of government spending on environmental protection represents the scale effect, whereas the squared term captures the combined composition and technique effects. If the data do not support a nonlinear relationship, the analysis relies on a linear model, in which government spending reflects the overall (net) effect of scale, composition, and technique changes. In addition, this study provides a comparative assessment of spending by local governments, the central government, and non-governmental sectors, extending previous research that has primarily focused on local government spending (Cui et al., 2021; Yang et al., 2021).

RESEARCH METHODS

The data used in this research consist of panel data for all 34 provinces in Indonesia covering the period 2017–2022. The data were obtained from the Ministry of Environment and Forestry of the Republic of Indonesia, the Ministry of Finance of the Republic of Indonesia, and BPS–Statistics Indonesia. Data from the Ministry of Environment and Forestry include the provincial Water Quality Index (WQI). Data from the Ministry of Finance includes the realization of central and local government spending. Data from BPS–Statistics Indonesia include the costs of maintaining water sources by clean water service provider companies, the number of large and medium manufacturing companies, the number of households, and the amount of rainfall.

This study employs a reduced-form model derived from the conceptual framework of López et al. (2011). In this study, the public goods referred to in the conceptual model are specifically related to environmental protection. The realization of environmental protection spending by provincial and regency/municipal governments within each province is aggregated because water pollution control efforts within a province are implemented jointly across different levels of local government. The quadratic term of the spending variable represents the combined effects of composition and technique.

Since the Water Quality Index (WQI) has the opposite interpretation of pollution (higher values indicate better environmental quality), the hypothesis of this study is formulated as the inverse of the augmentation curve proposed by López et al. (2011). Specifically, the hypothesis suggests that an initial increase in local government spending on environmental protection may decrease the water quality index. However, once a threshold is reached, further increases in spending are expected to improve it.

Table 1. Variable and Data

Variables	Data Sources	Definition
Water quality index (WQI)	Ministry of Environment and Forestry, Republic of Indonesia	Composite value of province-i's water quality parameter on year-t.
Local government spending (LOC)	Ministry of Finance, Republic of Indonesia	Realization of environmental protection spending of the provincial government in province-i plus environmental protection spending of all regency/municipality governments in province-i on year-t, in billion rupiah
Central government spending (CEN)	Ministry of Finance, Republic of Indonesia	Lag of 1 year of realization of wastewater management system spending of all central government units in province-i year-t, in billion rupiahs
Clean water service provider companies spending (WAT)	BPS- Statistics Indonesia	Cost of maintaining water sources by all clean water service provider companies in province-i on year-t, in billion rupiahs
Natural logarithm of the number of industrial companies (IND)	BPS- Statistics Indonesia	Natural logarithm transformation of the number of large and medium industrial/ manufacturing companies in province-i on year-t
Natural logarithm of the number of households (HH)	BPS- Statistics Indonesia	Natural logarithm transformation of the number of households in province-i on year-t
Rainfall (RAIN)	BPS- Statistics Indonesia	Total rainfall in province-i in year-t

Furthermore, in light of Government Regulation No. 22/2021, the model is modified by adding proxies for non-governmental efforts: central government spending on wastewater management systems and spending by clean water service provider companies on water source maintenance. Central government spending on wastewater management is included with a one-year lag, because the construction of wastewater management systems across provinces and national strategic areas represents a flow value of capital formation that does not generate outcomes in the same year. This contrasts with the realization of local government spending on environmental protection, where the proportion of capital formation in local spending is only about 20%. Meanwhile, spending by clean water service providers on water source maintenance is not lagging, as this spending has a more immediate impact on watersheds.

The model is estimated using the fixed-effects panel method because the ordinary least squares (OLS) estimator may still introduce bias. Government decisions regarding spending allocation are not random. Factors influencing these decisions can be partially controlled by including control variables, namely the number of large and medium manufacturing companies and the number of households. However, unobserved influences may still exist. Individual fixed effects help reduce bias arising from provincial characteristics that do not change over time, whether observable—such as the number of watersheds and the geographical characteristics of rivers—or unobservable, such as culture and environmental awareness. Time-fixed effects help reduce bias from shocks that occur in a particular year across all provinces, such as the COVID-19 pandemic and the Pemulihan Ekonomi Nasional (National Economic Recovery) policy in 2021, which may influence government spending allocations.

Water quality conditions in a given year may potentially influence subsequent budgetary decisions. To assess the possibility of reverse causality, this study employs the Dumitrescu–Hurlin (2012) panel Granger causality test as a diagnostic check. For datasets with a relatively small number of time periods, the Z-tilde test statistic is preferred over the Z test statistic (Lopez & Weber, 2017). Due to the limited time dimension of the main dataset, additional periods are included solely to satisfy the minimum requirements of the test. These additional periods are not used in the regression analysis because other variables are unavailable. The test results for panel data covering the period 2015–2023 show that the water quality index does not Granger-cause local government spending on environmental protection, as indicated by the p-value of the Z-tilde statistic. Therefore, there is no evidence of reverse causality from water quality to government spending. Thus, the model used in this study is:

$$WQI_{it} = \alpha + A_i'\gamma + \lambda_t + \rho_{11}LOC_{it} + \rho_{12}(LOC_{it})^2 + \rho_2 CEN_{it} + \rho_3 WAT_{it} + \delta_1 LnIND_{it} + \delta_2 LnHH_{it} + \delta_3 RAIN_{it} + \varepsilon_{it} \quad ...(1)$$

Where WQI_{it} is a dependent variable represented by the water quality index of province-i on year-t, LOC_{it} is an independent variable measured by adding the realization of environmental protection spending of province-i governments with the realization of environmental protection spending of all regency/ municipality governments in province-i on year-t, $(LOC_{it})^2$ is used to see the combined effects of composition and technique on the government spending, CEN_{it} is one year lagged of the realization of central government spending on wastewater management in province-i on year-t, and WAT_{it} is all clean water service provider companies spending on water source maintenance in province-i in year-t. Whereas IND_{it} is the number of large and medium manufacturing companies and HH_{it} is the number of households. Meanwhile, $A_i'\gamma$ is the individual fixed effect of province-i, λ_t is the time fixed effect of time-t, and ε_{it} is the error term.

RESULTS AND DISCUSSION

Based on the Water Quality Index (WQI) series for 2017–2022, the provinces with the lowest water quality are on Java Island, while those with the highest are outside Java. The number of large manufacturing companies, categorized as part of the dirty sector according to López et al. (2011), is significantly higher in provinces with a lower water quality index than in provinces with higher water quality.

Meanwhile, the patterns of average local government spending on environmental protection and average central government spending on wastewater management systems show a substantial decline in 2020, followed by a rebound in 2021, driven by fiscal reallocation policies during the COVID-19 pandemic. In addition, social restriction policies influenced the behavior of economic agents in polluting, which in turn affected the implementation of government spending on restoring water quality.

In contrast, spending by clean water service provider companies on water source maintenance appears to have been less affected by the COVID-19 pandemic. The average spending remained relatively stable during 2017–2021, at around IDR 4 billion. This suggests that increased household activities during the pandemic shifted the distribution of clean water consumption from the office to the household sector, while overall demand remained relatively stable.

Table 2. Statistics Descriptive of Main Variables

Variables	Obs	Mean	Med	Std. Dev	Min	Max
Water quality index (WQI)	204	54,81	54,32	9,85	20,19	82,50
Local government spending (LOC)	204	694,84	391,41	858,38	70,44	5.046,38
Central government spending (CEN)	204	31,62	14,23	47,55	0	269,22
Clean water service provider companies spending (WAT)	204	4,27	1,69	6,43	0,06	34,84

Source: Data Processed, 2025

The estimated impact of government spending on the Water Quality Index (WQI) in Indonesia is presented in Table 3 (quadratic model) and Table 4 (linear model). In Table 3, column (1), the quadratic model without year fixed effects and control variables initially suggests a nonlinear relationship between local government environmental spending and water quality, which is consistent with the augmented Environmental Kuznets Curve (EKC).

However, once year fixed effects and the relevant control variables are included, both the linear and quadratic terms become statistically insignificant. This indicates that the previously observed nonlinear relationship is not robust. Consequently, its economic significance is not further elaborated.

Table 3. Estimation Results of the Quadratic Model

	(1) WQI	(2) WQI	(3) WQI	(4) WQI
LOC	-0,0069* (0,065)	-0,00209 (0,617)	-0,00100 (0,812)	-0,000424 (0,928)
LOC2	0,00000150** (0,029)	0,00000100 (0,165)	0,000000857 (0,240)	0,000000716 (0,331)
CEN			0,00149 (0,930)	-0,00459 (0,791)
WAT			0,327** (0,035)	0,323** (0,036)
LnIND				-3,102 (0,552)
LnHH				-7,759* (0,093)
RAIN				0,00242** (0,054)
Cons.	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes
Obs.	204	204	204	204
R-squared	0,028	0,220	0,241	0,271

Note: p-value in parentheses. * p<0,10; ** p<0,05; *** p<0,001

To formally assess whether the quadratic specification provides additional explanatory power, the quadratic and linear models are compared using a likelihood ratio (LR) test. The LR test results indicate that the additional quadratic term does not significantly improve the model's goodness-of-fit. In other words, the linear specification is more appropriate for the data. This implies that the U-shaped relationship predicted by the augmented Environmental Kuznets Curve (EKC) is not statistically supported in this study.

Accordingly, the linear model in Table 4 is used as the main specification for analysis and discussion. The results show only minor coefficient adjustments across specifications, while central government spending remains consistently insignificant, indicating that the estimates are relatively robust.

The linear model in Table 4 indicates that the estimated coefficients capture the net effects of scale, composition, and technique. Focusing on the fully specified model in column (3), at a confidence level of 93.1%, every IDR 1 billion increase in the realization of local government spending on environmental protection at the provincial and regency/municipal levels (in aggregate) increases the Water Quality Index (WQI) in the province by 0.00328 index points, ceteris paribus. In comparison, at a higher confidence level (97.4%), every IDR 1 billion increase in clean water service provider companies' spending on water source maintenance increases the WQI by 0.340 index points, ceteris paribus. This finding is consistent with previous studies (Fan et al., 2022; López et al., 2011).

Table 4. Estimation Result of Linear Model

	(1) WQI	(2) WQI	(3) WQI
LOC	0,00316* (0,081)	0,00349* (0,053)	0,00328* (0,069)
CEN		-0,00132 (0,938)	-0,00747 (0,661)
WAT		0,346** (0,025)	0,340** (0,026)
LnIND			-4,049 (0,430)
LnHH			-7,625* (0,098)
RAIN			0,00254** (0,044)
Cons.	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	204	204	204
R-squared	0,211	0,235	0,267

Notes: p-value in parentheses. * p<0,10; ** p<0,05; *** p<0,001

Source: Data Processed, 2025

The positive impact of local government spending suggests that the combined composition and technique effects dominate the scale effect. One key transmission channel operates through local governments' supervisory role over potentially polluting activities. With sufficient budget allocation, stricter supervision encourages compliance with effluent standards and wastewater treatment requirements. This can reduce output in pollution-intensive sectors (composition effect) or induce firms to adopt cleaner production technologies without reducing output (technique effect). Consistent with this mechanism, the proportion of dirty sectors (agriculture, mining, and manufacturing) in gross domestic product (GDP) has been continuously declining.

Although statistically significant, the economic magnitude of local government spending remains relatively small. Based on the average growth in local government spending on environmental protection during 2017–2022 (17.11%) and the average spending value (IDR 694.84 billion), the increase in spending would amount to IDR 118.89 billion. According to the estimation results, an additional IDR 118.89 billion in spending would increase the Water Quality Index (WQI) by 0.389 index points. In contrast, the 2022 Ministry of Environment and Forestry Performance Report indicates that an increase of 1.42 index points was required for the national WQI to meet the 2022 target. Therefore, if the burden were placed solely on local governments, the average spending requirement is estimated at IDR 432 billion.

The limited economic magnitude indicates that the composition and technique effects generated by local government spending on environmental protection remain relatively weak. In practice, the transmission mechanism may be disrupted before reaching its intended outcome. For example, increases in human capital resulting from higher spending on public goods—such as environmental protection—require additional stimuli, such as technology adoption or research and development, to effectively change production techniques. Evidence from several Local Government Performance Reports shows that regency and municipal governments tend to allocate spending toward solid waste management, while provincial governments focus more on water quality monitoring. Meanwhile, spending on programs that directly intervene in water pollution–intensive business activities remains limited. The IDR 432 billion estimated to achieve the national WQI target could therefore be redirected toward technology adoption and firm-level environmental innovation, thereby strengthening the technique effect and enhancing the effectiveness of environmental protection spending.

Meanwhile, there is insufficient evidence to conclude that a 1-year lag in central government spending on wastewater management systems improves water quality. Under Act Number 23 of 2014, local wastewater management systems fall under the authority of local governments. Spending related to these systems is included in local government environmental protection expenditure, as specified in Ministerial Decree of the Ministry of Home Affairs Number 050-3708 of 2020. According to Act Number 23 of 2014, wastewater management systems under the authority of the central government involve inter-provincial and nationally strategic infrastructure, such as centralized domestic wastewater management systems. Such large-scale infrastructure projects are often implemented over multiple years, meaning that spending realization and the resulting outcomes—such as improvements in water quality—may not be observable in the short term.

On the other hand, spending by clean water service provider companies on water source maintenance is shown to increase the water quality index. Although the estimated coefficient remains relatively small, it is still larger than the coefficient of local government environmental protection spending. Every IDR 1 billion increase in these companies' spending on water source maintenance raises the WQI by 0.34 index points, assuming other variables remain constant. This result is consistent with previous studies (Yang et al., 2021; Cui et al., 2021). Private sector investment in environmental protection is more effective than government spending in reducing water pollution (Yang et al., 2021). Expenditures on water source maintenance represent direct environmental protection actions undertaken by clean water service provider companies, making them more effective. In addition, most clean water service provider companies are regionally owned enterprises (BPS-Statistics, 2022). As noted by Cui et al. (2021), the relationship between local-owned enterprises and local governments can facilitate stronger enforcement of water pollution control policies.

The estimation results also show that domestic activities, proxied by the number of households, contribute to increased water pollution. At a 90% confidence level, every 1% increase in the number of households in a province reduces the WQI by 0.0762 index points, holding other variables constant. Meanwhile, there is insufficient evidence to support the impact of the number of large and medium-sized industrial companies on WQI. Under Government Regulation No. 22 of 2021, efforts to control household pollution include the development of wastewater management systems. Data from the 2022 National Socioeconomic Survey show that only 13.22% of households use wastewater management systems. In contrast, efforts to control industrial pollution are more stringent because regulations apply from the business licensing stage through production and wastewater treatment processes.

On the other hand, rainfall shows a positive relationship with water quality. This finding is consistent with previous studies showing that decreases in rainfall can degrade water quality, as reduced water flow increases pollutant concentrations (Mahmoodi et al., 2021; Qiu et al., 2023). However, the magnitude of this effect is very small. At a 95.6% confidence level, every 1% decrease in rainfall within a province reduces the WQI by 0.0000254 index points, ceteris paribus.

Table 5. Estimation Result for All Observations (1) and 25% Observation with Highest LOC (2)

	(1) WQI	(2) WQI
LOC	0,00328* (0,069)	0,00349* (0,086)
CEN	-0,00747 (0,661)	-0,0184 (0,386)
WAT	0,340** (0,026)	0,726*** (0,007)
LnIND	-4,049 (0,430)	-0,434 (0,978)
LnHH	-7,625* (0,098)	-17,55 (0,575)
RAIN	0,00254** (0,044)	0,00181 (0,467)
Cons.	Yes	Yes
Provincial FE	Yes	Yes
Year FE	Yes	Yes
Obs.	204	51
R-squared	0,267	0,532

Notes: p-value in parentheses. * p<0,10; ** p<0,05; *** p<0,001

Source: Data Processed, 2025

The main results of the estimation show that the impact of government spending on environmental protection is relatively small. An exploratory analysis conducted as part of the preliminary analysis aims to identify the spending range at which the effect becomes economically meaningful. To maintain sufficient statistical reliability, the spending distribution is partitioned into quartiles rather than finer groupings such as deciles, which would substantially reduce the number of observations and increase estimation noise.

A negative trend is observed in the first quartile. In contrast, a weak positive pattern emerges in the second quartile but is not sustained in the third quartile, suggesting that the overall relationship does not follow a quadratic pattern. In the fourth quartile, the pattern begins to exhibit curvature, with indications of a turning point and a more clearly positive trend toward the upper tail of the distribution.

These patterns suggest that improvements in the Water Quality Index (WQI) may only become apparent once government spending on environmental protection reaches a sufficiently high level, providing a rationale for focusing on the fourth quartile of the spending distribution. Therefore, the subsample analysis focuses on the top 25 percent of observations with the highest levels of local government spending on environmental protection.

Table 5 compares the estimation results between the baseline model using all observations (column 1) and the subsample model including the top 25 percent of observations with the highest levels of local government spending on environmental protection (column 2). The results show a slightly larger impact of local government spending in the subsample. In regions where local government spending on environmental protection exceeds IDR 775.04 billion, a IDR 1 billion increase in such spending increases the Water Quality Index (WQI) by 0.00349 index points.

Although this effect is larger than the baseline estimate, its magnitude remains insufficient to close the national WQI target gap. A notable difference emerges in the spending of clean water service providers on water source maintenance. In regions where local government spending on environmental protection exceeds IDR 775.04 billion, a IDR 1 billion increase in such spending increases the WQI by 0.726 index points.

CONCLUSION

The results of this study indicate that the relationship between local government spending on environmental protection and the Water Quality Index (WQI) does not follow a quadratic pattern. Therefore, the observed effect reflects the combined influence of scale, composition, and technique effects. The implementation of local government spending on environmental protection has a statistically significant effect on the WQI, ceteris paribus. However, the effect's magnitude remains very small. Even among the top 25 percent of regions with the highest levels of local government spending on environmental protection, the impact remains only slightly larger.

This finding suggests that the combined effects of composition and technique generated by government spending on environmental protection remain limited. To achieve the national WQI target, if the responsibility were placed solely on local governments, the average spending requirement is estimated at IDR 432 billion. This amount could be allocated to corporate-level interventions, such as supporting research and the adoption of cleaner technologies. Such measures could strengthen the technique effect and reduce potential disruptions in the transmission mechanism of environmental protection spending.

Although the estimated coefficient is small, local government spending still shows a significant effect on wastewater management system outputs relative to central government spending in the regions. This difference is related to the large scale of infrastructure projects, which typically require longer periods before their effects on surface water quality become observable. Therefore, the government should consider developing localized wastewater management systems while still accounting for the necessary technical considerations.

Furthermore, compared with spending by clean water service providers on water source maintenance, this type of spending appears more effective than government spending. In the top 25 percent of regions with the highest levels of local government environmental protection spending, the impact is even greater. Therefore, local governments should not only enforce regulations on wastewater disposal, but also require water supply companies and/or regionally owned enterprises that use surface water to undertake water source maintenance activities.

The findings of this study may also serve as a reference for the central government agency responsible for environmental affairs in developing an Environmental Quality Response Index. This index reflects local governments' responses to components of the Environmental Quality Index, including the WQI, through both management and technical approaches. In developing this index, the government may consider incorporating variables related to clean water service providers or regionally owned enterprises into the stakeholder engagement indicators.

It should be noted that these conclusions are based on estimates that contain several limitations. The measure of local government spending used in this study represents spending on environmental protection functions that are not specific to water quality. This category also includes expenditures related to natural resource conservation, spatial planning, and land management. In addition, prior to the implementation of the 2020 Ministerial Decree, local governments may not have classified spending on wastewater management systems under this function.

Therefore, if sufficient data become available following the 2020 Ministry of Home Affairs regulation, future research could employ more specific expenditure data, such as spending under the wastewater management sub-function. To reduce potential classification errors by local governments in functional expenditure coding, future studies may also consider using program-level expenditure codes that are directly related to water or wastewater quality.

Similarly, the proxy for central government spending may be underestimated because it excludes expenditures from directorates responsible for water quality and wastewater management, whose spending cannot be disaggregated by region. Spending by the water pollution control directorate, for example, is not implemented through regional work units or through deconcentration mechanisms, making it difficult to allocate geographically.

Finally, non-government sector spending may also be underestimated because this study only includes spending by clean water service provider companies. Information on environmental control costs incurred by other sectors was not available at the time this study was conducted.

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