

# Assessing Local Environmental Spending and Air Pollution Reduction in Indonesia: A Satellite Data Approach

Ega Kurnia Yazid<sup>1</sup>   Kelvin Ramadhan Hidayat<sup>1</sup>   Data Avicenna<sup>2</sup>   Muhammad Faiz Zaidan Alharkan<sup>3</sup>

<sup>1</sup>Policy Support Team, Coordinating Ministry of Social Empowerment, Indonesia

<sup>2</sup>Faculty of Economics and Business, Universitas Gadjah Mada, Indonesia

<sup>3</sup>Pertamina New & Renewable Energy, Indonesia

Accelerating Climate Action in Asia: Fiscal Policy Solutions  
ADB I Tokyo, 9-10 July 2025

# Presentation Outline

- 1 Introduction
- 2 Literature Review & Research Gap
- 3 Data & Methodology
- 4 Results
- 5 Conclusion

# Indonesia's Environmental Challenge

## Political & Environmental Concerns:

- Indonesia committed to **net-zero emissions by 2060** at COP26
- Currently among **top 10 global carbon emitters** (Union of Concerned Scientists, 2021)
- Decentralized governance requires local-level environmental action
- Limited progress in emission reduction at local level

## Data & Research Gaps:

- **Paucity of air pollution data** at local level. This highlights the need for alternative data sources for evaluation
- Most studies use general budget instead of environmental-specific spending

# Policy Context & Research Objective

- The Government of Indonesia mandates the local government to manage the environmental quality through **environmental funds** (Government Regulation No. 32 of 2009 concerning Environmental Economic Instruments and Presidential Regulation No. 77 of 2018 concerning the Management of Environmental Funds).
- This study focuses on **environmental spending of local governments**. The potential sources of environmental budget of local governments are:
  - Indonesia's national budget (APBN) through the Special Allocation Funds for Environmental Functions (DAK *Fungsi Lingkungan Hidup*) and General Allocation Funds (DAU)
  - Locally generated revenue

## Research Objective

This study, thus, aims to evaluate the effect of local environmental spending on pollution level.

# Literature Overview: Mixed Results (1/2)

Region/Country	Finding	Key Studies
World	Mixed results: insignificant relationship to positive impact on SO <sub>2</sub> emissions. Direct negative impact varies by income level.	Halkos & Paizanos (2013); Bernauer & Koubi (2013); Yilanci & Pata (2022)
Europe	Negative relationship - spending reduces SO <sub>2</sub> , NO <sub>2</sub> , and O <sub>3</sub> . Attributed to carbon taxes and governance quality.	Lopez & Palacios (2010); López & Palacios (2014)
USA	No significant effect of central government spending. Budget composition at state level more important than total amount.	Islam & López (2013); Halkos & Paizanos (2017)

# Literature Overview: Mixed Results (2/2)

Region/Country	Finding	Key Studies
China	Mixed results: negative impact on SO <sub>2</sub> but positive on chemical oxygen demand and soot. Spatial spillover effects between provinces.	Zhang et al. (2017); Huang (2018); Xiong et al. (2020)
Developing Asia	Context-dependent: large fiscal spending decreases pollution with shadow economy, increases with higher taxes.	Huynh (2020)
Indonesia	Limited evidence - positive relationship with Environmental Quality Index at provincial level. Uses general spending, not environmental-specific budgets.	Oktavilia et al. (2021)

# Research Gaps

- Most studies use **general government spending**
- Limited focus on **local-level analysis**
- Lack of **comprehensive analysis on various pollution types**
- Few studies in **developing countries**
- Indonesia-specific evidence is **very limited**

# Data Sources & Coverage

## Dataset Overview:

- **474 cities/regencies** across Indonesia (2011-2019)
- **4,266 observations** total
- Excludes DKI Jakarta (outlier) and administratively divided regions

## Air Pollution Data:

- **NASA Giovanni** satellite database
- Spatial resolution:  $13.75 \text{ km} \times 13.75 \text{ km}$
- Monthly data aggregated annually
- Pollutants:  $\text{NO}_2$ ,  $\text{SO}_2$ ,  $\text{PM}_{2.5}$ ,  $\text{O}_3$ , Black Carbon

## Budget & Control Data:

- **Environmental budget**: Ministry of Finance
- **Economic data**: SIMREG (BAPPENAS)
- **Geographic data**: USGS + QGIS
- Population density, elevation, GDP, industry share



# Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Obs
<b>Air Pollution Growth:</b>					
NO <sub>2</sub> Growth	-0.001	0.083	-0.231	0.187	3,724
SO <sub>2</sub> Growth	0.018	1.027	-6.431	6.043	3,359
PM <sub>2.5</sub> Growth	0.000	0.334	-1.797	1.341	3,318
O <sub>3</sub> Growth	0.001	0.025	-0.040	0.059	3,768
Black Carbon Growth	1.010	2.647	-2.105	8.906	3,700
<b>Key Variables:</b>					
Env. Budget Growth	0.093	0.745	-10.727	10.940	3,673
Population Density	999.8	2,296.3	0.85	16,208.7	4,266
Regional GDP (ln)	9.123	1.249	2.565	13.272	4,264

## Key Observations:

- Large variation in environmental budget growth (-10.7% to +10.9%)
- Most pollutants show near-zero average growth
- Substantial heterogeneity across regions

# Empirical Strategy

## Growth Rate Definition:

$$PollutionGrowth_{it} = \ln(Pollution_{it}) - \ln(Pollution_{it-1})$$

## Fixed Effects Model:

$$\begin{aligned} PollutionGrowth_{it} = & \alpha + \beta \cdot EnvBudgetGrowth_{it} \\ & + X'_{it}\gamma + Z'_{it}\delta + \omega_i + \phi_t + \epsilon_{it} \end{aligned} \quad (1)$$

Where:

- $X_{it}$ : Regional characteristics (population density, elevation)
- $Z_{it}$ : Economic characteristics (GDP, government spending, industry share)
- $\omega_i$ : City/regency fixed effects
- $\phi_t$ : Year fixed effects

# Main Results

	(1) Bivariate		(2) + Regional		(3) + Economic	
	SO <sub>2</sub>	NO <sub>2</sub>	SO <sub>2</sub>	NO <sub>2</sub>	SO <sub>2</sub>	NO <sub>2</sub>
<b>Env. Budget</b>	0.130 (0.270)	<b>-0.010**</b> (0.004)	0.132 (0.028)	<b>-0.018*</b> (0.010)	0.107 (0.300)	<b>-0.016*</b> (0.011)
Pop. Density			-0.184*	0.039**	-0.202*	0.039**
Elevation			0.100**	-0.004**	0.090*	-0.004***
ln(Regional GDP)					2.600	0.003
ln(Total Gov. Spend.)					0.130	-0.007
Share of Industry					1.001	-0.004
Fixed Effects			Year + City/Regency: Yes			
N	3,314	3,673	3,195	3,545	3,194	3,544
Adj. R <sup>2</sup>	0.048	0.829	0.048	0.834	0.048	0.834

## Key Findings:

- Environmental budget **significantly reduces NO<sub>2</sub> pollution**
- **No significant effect on SO<sub>2</sub> pollution**
- Results consistent across specifications

# Effect Magnitude & Economic Interpretation

## Main Finding

A **10% increase** in environmental budget spending is associated with a **0.16% reduction** in NO<sub>2</sub> pollution growth

## Economic Interpretation:

- **Inelastic relationship** - spending increases do not translate proportionately to pollution reduction
- Suggests **inefficiencies** in current environmental spending
- NO<sub>2</sub> reduction likely due to programs targeting **fuel combustion sources** (vehicles, power plants)
- SO<sub>2</sub> unaffected suggests programs do not address **industrial pollution sources**

# Heterogeneity Analysis: Income Levels

	Q1 (Poorest)		Q2		Q3		Q4 (Richest)	
	SO <sub>2</sub>	NO <sub>2</sub>	SO <sub>2</sub>	NO <sub>2</sub>	SO <sub>2</sub>	NO <sub>2</sub>	SO <sub>2</sub>	NO <sub>2</sub>
<b>Env. Budget Growth</b>	<b>-0.961*</b> (0.574)	<b>-0.036*</b> (0.019)	0.127 (0.086)	<b>-0.047*</b> (0.027)	0.397 (0.559)	0.014 (0.018)	-0.194 (0.599)	-0.008 (0.017)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	807	883	796	914	842	908	749	839

## Key Insights:

- Environmental spending **more effective in poorer regions**
- Effect becomes **insignificant in wealthier areas**
- Suggests **diminishing returns** with economic development

# Temporal Dynamics & Other Pollutants

## Lagged Effects:

- **No significant lagged effects** found
- Environmental spending only affects pollution in **current year**
- Suggests **short-term focus** rather than sustainable programs

## Policy Concern:

- Programs may focus on **budget absorption** rather than long-term environmental improvement

## Other Pollutants:

Pollutant	Effect
NO <sub>2</sub>	-0.016*
SO <sub>2</sub>	0.107
O <sub>3</sub>	-0.005**
PM <sub>2.5</sub>	0.019
Black Carbon	+0.160**

## Mixed Results:

- **Effective** for NO<sub>2</sub> and O<sub>3</sub>
- **No effect** on SO<sub>2</sub> and PM<sub>2.5</sub>
- **Increases** Black Carbon

# Conclusion

## Key Findings:

- Environmental spending significantly reduces NO<sub>2</sub> pollution but shows no significant effect on SO<sub>2</sub> levels
- Budget effectiveness is inelastic - 10% budget increase yields only 0.016% NO<sub>2</sub> reduction
- Environmental programs show short-term impact only with no lasting effects in subsequent years
- Effects are stronger in economically disadvantaged areas compared to wealthier regions

# Policy Implications

- Current programs primarily target vehicle and power plant emissions ( $\text{NO}_2$  sources)
- Need for programs addressing industrial pollution sources ( $\text{SO}_2$  emissions)
- Efficiency improvements required for optimal budget utilization
- Taking advantage of satellite data for evaluation
- Focus on sustainable, long-term environmental strategies rather than short-term measures



# Limitations

- Natural phenomena (e.g. forest fires, volcanic eruptions) and other possible factors that may influence pollution levels not controlled
- Cannot isolate specific environmental programs within environmental spending within local governments

# Thank You!

Contact: [ega.yazid@kemenkopm.go.id](mailto:ega.yazid@kemenkopm.go.id)