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Effects of Environmental Protection Expenditures on Provincial Environmental Protection Performance

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Abstract

Amid rising environmental pressures in emerging economies, the effectiveness of public environmental spending remains an open question. Vietnam, undergoing rapid industrialization and urban expansion, offers a unique setting to assess whether fiscal efforts translate into tangible environmental improvements. This study investigates the impact of provincial environmental protection expenditures (EPE) on air, water, and land quality across 63 provinces from 2019 to 2023. Building upon the Driving Forces–Pressures–State–Impacts–Responses (DPSIR) framework, panel models and a Seemingly Unrelated Regression (SUR) system are employed to capture interlinked environmental outcomes. The findings reveal domain-specific effects: EPE significantly enhances wastewater treatment coverage, yet exhibits limited short-term influence on air pollution or land-use transitions. Socio-economic factors such as Human Development Index (HDI) and population density also shape environmental performance, improving emission efficiency and clean water access.These results underscore that fiscal environmental investments in Vietnam yield selective rather than universal benefits, emphasizing the importance of integrated, spatially targeted, and long-term fiscal strategies for sustainable environmental governance.

Keywords: Air quality, environmental protection expenditure, environmental protection performance, land use, water quality.

1. Introduction

Globalization and rapid economic development have brought significant advancements to many countries around the world, but at the same time, they have also caused increasingly severe environmental challenges, and Vietnam is facing many environmental issues. Vietnam is among the most vulnerable countries to climate change. With limited adaptive capacity, climate shocks are likely to exacerbate inequalities in health protection, restrict access to food and clean water, and hinder poverty reduction efforts [1]. In this context, studying the relationship between financial efforts, specifically, spending on environmental protection, and the outcomes achieved in improving environmental quality becomes extremely urgent. This research aims to clarify this relationship across the 63 provinces of Vietnam.

Human-caused climate change is already affecting weather and climate extremes in every region across the globe. This has resulted in widespread negative impacts on food and water security, human health, economies, and society, along with associated losses and damages to both nature and people [2]. Currently, in Vietnam, we are facing an astonishing situation: approximately 60,000 tons of household waste are discharged into the environment every day. According to the Ministry of Natural Resources and Environment, over 70% of this waste is treated through landfilling, but less than 20% is hygienically buried. Unhygienic landfilling is daily causing pollution to the land, water, and air environments [3]. With nearly 100 million people and rapid urbanization, Vietnam generates around 68,000 tonnes of solid waste every day, 60% of which comes from urban areas. This is expected to swell by 16% by 2025, straining the country's 1,200 dumps, where about two-thirds of waste ends up [4]. Ho Chi Minh City, Vietnam's largest and most densely populated urban center, is home to over 9 million people. With rapid urbanization and economic growth, the city generates an average of 13,000 tons of domestic solid waste per day as of 2024. Of this total, approximately 10,000 tons are recycled or treated daily [5].

Water pollution, both in Vietnam and globally, has become a serious and urgent issue. Wastewater includes wastewater sources from household activities, businesses, and service industries such as restaurants, hotels, and resorts. Although domestic wastewater accounts for more than 30% of the total amount of water directly discharged into the environment, the level of collection and treatment is still very low [6]. Natural Resources and Environment and Health Ministries claim that 9,000 people die every year due to poor sanitation and water quality, nearly 250,000 people are hospitalized because of acute diarrhea caused by contaminated domestic water, and some 200,000 have

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cancer linked to water pollution. These threats, cascading through the economy now, are already causing damage. Economic losses, currently estimated at 1.5% per year, are forecasted to rise sharply: to 3% per year by 2050 and to as much as 7% by 2100, among the highest in the world [7].

Agriculture produces vast quantities of waste from fertilizers, pesticides, pathogens, and pharmaceuticals that are fed to animals. Some 95 percent of livestock waste generated each year enters the environment untreated, carrying nutrients, pathogens, and volatile compounds that pollute water and air, and damage land uses [7]. As growth in cities outpaces the capacity of urban infrastructure, many mid- to low-income farmers, for whom clean freshwater is either unavailable or too costly, turn to untreated wastewater as a solution [8]. Agriculture comprises over 70 percent of freshwater use worldwide. Of this whithin, at least 200 million farmers irrigate 20 million hectares with wastewater [8].

Forest land plays a vital role in the global ecosystem, but when exploited unsustainably, it can have serious consequences. Forests occupy 31% of the Earth's land area and serve as a vital buffer against climate change, according to the United Nations. Asia hosts some of the planet's most diverse and species-rich forests. However, according to [9], between 1990 and 2020, the world lost about 420 million hectares of forest due to land use conversion, although the rate of deforestation has decreased over the past three decades. Deforestation not only reduces forest area but also leads to land erosion, loss of biodiversity, and increased greenhouse gas emissions. According to Climate Impact Partners (2024), deforestation accounts for around 12–20% of global greenhouse gas emissions. Deforestation of tropical rainforests is a major source of these emissions. Because of their high growth rate, tropical rainforests have a high capacity for storing carbon, more than any other forest type.

Air quality is worsening across the globe. The State of Global Air Report 2024 revealed that in 2021, air pollution was responsible for 8.1 million deaths worldwide, ranking as the second leading risk factor for mortality, and contributed to many health issues, including heart, lung, and respiratory diseases [10]. Air pollution levels are rising in most low- and middle-income countries, yet international development funding for clean air initiatives remains inadequate [11], leaving these nations to devise their own strategies for improvement.

In the context of rapid development and strong urbanization, public expenditure on environmental protection is increasingly recognized as an important economic tool to enhance the effectiveness of environmental management and to move towards sustainable development. Environmental protection expenditure consists of the economic resources devoted to all activities and actions which have as their main purpose the prevention, reduction, and elimination of pollution and of any other degradation of the environment. Those activities and actions include all measures taken in order to restore the environment after it has been degraded [12].

According to the Law on Environmental Protection No. 72/2020/QH14, environmental protection is the right, obligation, and responsibility of all agencies, organizations, residential communities, households, and individuals. Theoretically, this study contributes by deepening the understanding of the relationship between state budget expenditure on the environment and the quality of environmental protection, especially in the context of a developing economy like Vietnam. Practically, this study evaluates whether allocated resources bring about the desired environmental outcomes. The study includes an introduction, a theoretical overview, research methodology, results and discussion, and conclusion.

2. Literature Review and Hypothesis Development

Economic prosperity and environmental quality are widely regarded as two of a nation's most important goals, especially in the current context when countries are moving towards sustainable development. Vietnam's capacity for responding to climate change remains limited, making the country vulnerable to natural disasters. The dissemination of climate change adaptation and low-carbon development models, as well as the application of renewable energy and waste-to-energy technologies, currently faces numerous difficulties. Therefore, investment from the state budget in environmental protection needs to be increased, while the operational efficiency of environmental protection funds should also be improved [13].

As mentioned, air quality around the world, including in Vietnam, is deteriorating due to the impact of climate change and human-caused pollution such as waste discharge, garbage burning, and fuel combustion. For the case of China, air quality management approaches have reduced air pollution and improved air quality [10]. Over the years, in order to improve air quality and reduce environmental pollution, many countries have spent a large part of their environmental protection budget on renewable energy projects, clean energy, exhaust gas treatment, industrial waste management, pollution control, as well as tree planting and green space protection. The study by [14] also suggests that governments in developing countries should continue to prioritize environmental spending within fiscal reform policies to enhance air pollution control.

Through the signal effect of fiscal expenditures, the government can guide society to engage in green innovation and encourage enterprises to fulfill their responsibilities [15]. The synergetic effect of environmental protection expenditure and green technology innovation on corporate financial performance is more significant in enterprises with high corporate governance levels [16]. Research on institutional capacity often assumes that industrial ecology policies, such as water use efficiency, foster and positively reinforce relationships between government and industrial zones [17]. Confirmed dependencies show that expenditure on waste management is efficiently spent, contributing to the achievement of environmental policy objectives more effectively [18]. In consequence, the government should provide loans and lower financing costs to support wastewater treatment and reuse [19].

Besides, this is a challenge that increasingly affects the environment, particularly water resources [20]. Governments use different policy goals and measures in conjunction to promote transition [21]. In developing countries, a vicious circle composed of complex and interconnected challenges has historically hindered the advancement of disruptive and sustainable water treatment technologies [22]. A prime reason for not treating wastewater is its expensive nature and lack of law enforcement [13]. Reducing canal water pollution and raising awareness of local stakeholders of the potential of nature-based water treatment systems to contribute to addressing critical sustainability challenges is essential [23]. Therefore, the most effective solution is for governments to allocate financial resources and actively support infrastructure development, ensuring sustainable water resources.

Environmental protection expenditures are also redefining the conventional approach to urban land use planning and influencing the emphasis on sustainability [24]. Land-use planning is considered an ideal tool to allocate and reallocate land resources for development and sustainable development purposes [25]. Based on land use planning, there is a legal basis for land allocation, land lease, and land recovery for economic and social development projects such as urban development, construction of commercial centers, industrial development, and road construction. The integration of water resources management strategies in land use planning is crucial for achieving environmental conservation, sustainable development, and improved resilience to environmental challenges [26].

A province is considered to have good environmental governance quality when it makes efforts to prevent and minimize environmental pollution and the negative impacts of climate change [27]. The Environmental Performance Index (EPI) is a biennial global ranking of countries' efforts to protect human environmental health and manage natural resources and ecosystems [21]. According to earlier research, undertaking the implementation of a feasibility study in developing Vietnam's EPI was a step forward in assessing the state of environmental data at the provincial level [21]. In recent years, Vietnam's EPI has been constantly changing, and the 2024 data show that Vietnam's score has decreased by 4.6 points compared to the reference point 10 years ago [28]. Improving Vietnam's EPI is essential for sustainable development, requiring a shift from a resource-based economy to one driven by high-quality human resources, science, and technology, leveraging Industry 4.0 advantages [4].

Therefore, the following hypotheses are proposed:

H1. *Environmental protection expenditure contributes positively to the improvement of air quality.*

H2. *Environmental protection expenditure contributes positively to sustainable land use.*

H3. *Environmental protection expenditure contributes positively to the enhancement of water quality.*

3. Data and Methods

According to [29], Vietnam's environmental reporting framework classifies environmental issues into seven main pillars: (1) residential living environment, (2) land and biodiversity, (3) air, (4) water, (5) solid waste, (6) natural disasters, and (7) energy consumption. Each pillar, except for environmental protection and management budgets, is analyzed through the Driving Forces–Pressures–State–Impacts–Responses (DPSIR) framework, which conceptualizes the causal chain linking socio-economic activities, environmental conditions, and policy responses. This integrated approach to environmental statistics is also endorsed by [30], which provides the conceptual foundation for organizing environmental indicators used in this study.

Specifically, the present study focuses on four key pillars: (i) environmental protection and management, measured through fiscal expenditure on environmental protection; (ii) land usage, represented by urban, forest, and agricultural land use; (iii) water quality, measured by access to clean water and wastewater treatment rates; and (iv) air quality, represented by atmospheric pollutant concentrations.

Therefore, a set of variables is defined in Table 1. The data cover the period from 2019 to 2023. Financial data were obtained from the Ministry of Finance, while information on water use, land use, and other control variables was sourced from the General Statistics Office. Province-year $PM_{2.5}$ was derived in Google Earth Engine from the Copernicus Atmosphere Monitoring Service global near real-time product ECMWF/CAMS/NRT. The CAMS NRT product provides forecast fields at a native pixel size of about 44,528 m. For each year *t*, we aggregated the sub-daily forecast snapshots to quarterly means, then computed an annual composite as a day-weighted mean of the quarterly means. Finally, province-level annual $PM_{2.5}$ was obtained by spatially averaging the annual composite over each province polygon using *reduceRegions* with scale $\approx$ 44,528 m.

$PM_{2.5}$ from CAMS is a model-based, data-assimilated surface product rather than a direct measurement. We interpret it as a harmonized exposure proxy and apply robust inference, including clustered standard errors and sensitivity analyses. Where feasible, we validate the aggregated series against independent ground-monitoring data or published CAMS evaluations.

Fractional logit via GLM binomial and logit

Table 1. Summary of variables, units, and data sources

Category	Variable	Symbol	Unit	Measure / Meaning	Source
Air quality	Particulate matter $\leq 2.5\ \mu$m	$PM_{2.5}$	$\mu g/m^3$	Annual mean near-surface $PM_{2.5}$ concentration (province average)	*
Land use	Residential land share	resi_share	%	Share of provincial land classified as residential land	*
	Special / urban land share	sp_share	%	Share of provincial land classified as special / urban land	*
	Agricultural land share	agr_share	%	Share of provincial land classified as agricultural land	*
	Forestry land share	for_share	%	Share of provincial land classified as forestry land	*
Water quality	Urban population with access to clean water	Uws	%	Urban residents served by centralized clean water systems	**
	Industrial zones with wastewater treatment	Iwt	%	Industrial zones with centralized wastewater treatment plants	**
Socio-economic	Human Development Index	HDI	score	Composite index of health, education, and income	**
	Population density	Density	people/km^2	Residents per square kilometer	**
	Industrial Production Index	IPI	index	Provincial industrial production index	**
Expenditure	Environmental protection expenditure	EPE	billion VND	Provincial government budget for environmental protection	***

Notes: (*) Satellite- or model-based gridded datasets (e.g., ECMWF CAMS via Google Earth Engine). (**) General Statistics Office of Vietnam. (***) Ministry of Finance.

For province i in year t and environmental domain $j \in \mathscr{J}$, the dependent variable Y_{it}^{j} is a bounded share or rate:

$$\mathscr{J} = \{\text{Land, Water, Air}\}.$$

$$\begin{aligned} Y_{it}^{\text{Land}} &\in \{\text{agr\_share}_{it}, \text{forestry\_share}_{it}, \\ &\qquad \text{resi\_share}_{it}, \text{special\_share}_{it}\}, \\ Y_{it}^{\text{Water}} &\in \{\text{uws}_{it}, \text{iwt}_{it}\}, \\ Y_{it}^{\text{Air}} &\in \{\text{pm2.5}_{it}, \text{co}_{it}\}. \end{aligned}$$

To respect the fractional nature of these outcomes, we estimate a fractional logit model using a quasi-likelihood generalized linear model with binomial family and logit link:

$$\begin{aligned} \mathbb{E}\left[Y_{it}^{j} \mid \mathbf{X}_{it}, \mathbf{Z}_{it}^{j}\right] &= G\left(\eta_{it}^{j}\right), \\ \eta_{it}^{j} &= \beta_0^{j}\ \mathbf{X}_{it}'\beta^{j}\ \mathbf{Z}_{it}^{j\prime}\gamma^{j}. \end{aligned} \tag{1}$$

where $Gu = \{1\ \exp{-u}\}^{-1}$ is the logistic cumulative distribution function. The main regressors are

$$\mathbf{X}_{it} = \begin{pmatrix} \ln\left(1\ \text{EPE}_{it}\right),\ \ln\left(1\ \text{HDI}_{it}\right), \\ \ln\left(1\ \text{Density}_{it}\right),\ \ln\left(1\ \text{IPI}_{it}\right) \end{pmatrix}$$

and $\mathbf{Z}_{it}^{j}$ denotes optional domain-specific controls included when available. When variables are reported in percentages, outcomes are rescaled to the unit interval. To avoid boundary issues at 0 or 1, we apply a small smoothing transformation of the form $\tilde{Y} = \frac{Yn-10.5}{n}$ prior to estimation. Coefficients from (1) are in log-odds units, so we report average marginal effects for interpretation:

$$\text{AME}_k = \frac{1}{N}\ _{i,t}\ \frac{\partial \mathbb{E}Y_{it}^{j}|\cdot}{\partial X_{k,it}} = \frac{1}{N}\ _{i,t}\ G\eta_{it}^{j}\left(1 - G\eta_{it}^{j}\right)\beta_k. \tag{2}$$

All inference is conducted with province-clustered standard errors to account for heteroskedasticity and within-province dependence over time. After estimation, resampling is used to check model robustness by leaving one province out.

4. Results

4.1. Land Usage Quality

Descriptive statistics for the land-related model outcomes are reported in Table 2, while model diagnostics are shown in Table 3. The GLM average marginal effects results are presented in Table 4. Most covariates are statistically insignificant across land-use outcomes, except for the residential share. For *resi_share*, both EPE (lepe) and IPI (lipi) have negative and statistically significant average marginal effects ($p < 0.05$), implying a small decrease in the expected residential land share as EPE or IPI increases. In contrast, no covariate is significant for *agr_share*, *forestry_share*, or *special_share*.

Leave-One-Province-Out (LOPO) sensitivity analysis in Table 5 indicates that the estimated average marginal effect for population density is highly stable, with minimal coefficient drift and full persistence of significance. By contrast, HDI shows substantial

Table 2. Descriptive statistics for land-related model outcomes (2019–2023)

	Outcomes (shares)				Regressors (log-transformed)			
Statistic	resi_share	agr_share	forestry_share	special_share	lhdi	ldensity	lepe	lipi
Count	259	259	259	259	259	259	259	259
Mean	0.03	0.38	0.40	0.09	0.53	5.64	5.25	4.69
Std	0.03	0.20	0.26	0.07	0.02	0.88	0.74	0.06
Min	0.00	0.05	0.01	0.01	0.50	4.52	4.24	4.58
25%	0.01	0.21	0.12	0.04	0.52	4.70	4.75	4.65
50%	0.02	0.35	0.46	0.06	0.53	5.49	5.10	4.69
75%	0.05	0.52	0.60	0.09	0.55	6.38	5.67	4.74
Max	0.13	1.04	0.85	0.35	0.58	7.04	6.57	4.78

sensitivity, while EPE and IPI are comparatively fragile and rarely remain significant at the 5% level across LOPO runs.

Table 3. Model diagnostics across land-use outcomes

y	Max VIF	JB p	AR(1) $\hat{\rho}$	AR(1) p	BP-LM p	BP-F p
special_share	2.65	< 0.01	0.45	< 0.01	0.00	0.00
resi_share	2.65	< 0.01	-0.01	0.90	0.00	0.00
agr_share	2.65	< 0.01	-0.36	< 0.01	0.77	0.77
forestry_share	2.65	< 0.01	-0.01	0.80	0.06	0.06

Table 4. GLM marginal effects for land-use model

	agr_share	for_share	resi_share	sp_share
lhdi	0.01	0.03	0.01	0.18
	(0.13)	(0.04)	(0.01)	(0.27)
ldensity	-0.08	-0.15	0.00	-0.33
	(0.14)	(0.17)	(0.01)	(0.34)
lepe	0.00	-0.00	-0.00**	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
lipi	0.01	0.01	-0.00**	-0.01
	(0.03)	(0.03)	(0.00)	(0.01)

Notes: ** $p < 0.05$.

Table 5. LOPO sensitivity for land-use model

Y	X	Max $\lvert\Delta\rvert$	Sig (10%)	Sig (5%)
agr_share	lhdi	0.5467	1.0000	1.0000
agr_share	ldensity	0.0109	1.0000	1.0000
agr_share	lepe	0.0147	0.9107	0.2321
forestry_share	lhdi	0.3978	1.0000	1.0000
forestry_share	ldensity	0.0082	1.0000	1.0000
resi_share	ldensity	0.0022	1.0000	1.0000
special_share	lhdi	0.0881	1.0000	1.0000

4.2. Water Quality

Descriptive statistics for the water-related model outcomes are reported in Table 6. Diagnostic tests are shown in Table 7. Multicollinearity is negligible, so the regressor set is retained. Residual diagnostics indicate AR(1) dependence for *uws* and heteroskedasticity for *iwt*, motivating province-clustered inference in the main estimation.

The GLM average marginal effects are reported in Table 8. Population density is the only robust predictor across water outcomes: it is positive and statistically significant for both *uws* and *iwt*. The magnitude suggests that higher population density is associated with higher expected coverage or shares, holding other covariates constant. EPE, HDI, and IPI show imprecise average marginal effects, so evidence for their effects is weak in this specification. LOPO results in Table 9 indicate that inference is most stable for density, which remains statistically significant in almost all re-estimations. By contrast, HDI and partly IPI are highly sensitive.

Table 6. Descriptive statistics for water-related model outcomes (2019–2023)

	uws	iwt	lepe	lhdi	ldensity	lipi
Count	259.00	280.00	268.00	252.00	276.00	249.00
Mean	84.26	92.07	5.45	0.54	5.72	4.68
Std	27.61	10.41	0.98	0.02	0.83	0.06
Min	0.00	48.00	4.22	0.50	4.59	4.58
25%	75.74	89.00	4.75	0.52	4.94	4.64
50%	100.00	96.00	5.14	0.53	5.62	4.68
75%	100.00	99.00	6.13	0.55	6.39	4.73
Max	100.00	100.00	7.36	0.58	7.00	4.77

Table 7. Diagnostic tests for water outcomes

Y	Max VIF	AR1 $\hat{\rho}$	p	BP-LM p	BP-F p
uws	1.94	-0.14	0.02	0.10	0.10
iwt	1.94	-0.05	0.55	0.00	0.00

Notes: Max VIF is computed across the log-transformed regressors. AR(1) is estimated from within-province residuals. BP denotes the Breusch–Pagan heteroskedasticity test.

Table 8. GLM average marginal effects for water quality

	uws	*iwt*
lepe	-0.03 (0.04)	0.00 (0.01)
lhdi	0.81 (1.87)	0.29 (0.39)
ldensity	0.10** (0.05)	0.05*** (0.01)
lipi	0.28 (0.30)	0.04 (0.09)

Notes: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 9. LOPO sensitivity summary for water quality model

Y	Variable	Max $\|\Delta\|$	Mean $\|\Delta\|$	Share $p < 0.10$	Share $p < 0.05$
iwt	lhdi	2.22	0.40	0.00	0.00
iwt	lipi	0.40	0.09	0.00	0.00
iwt	ldensity	0.06	0.01	1.00	1.00
iwt	lepe	0.06	0.01	0.00	0.00
uws	lhdi	8.47	1.09	0.00	0.00
uws	lipi	1.41	0.20	0.00	0.00
uws	lepe	0.21	0.03	0.00	0.00
uws	ldensity	0.16	0.03	1.00	1.00

4.3. Air Quality

Descriptive statistics for the air quality model are presented in Table 10. The GLM Gamma–Log estimates for annual $PM_{2.5}$ are shown in Table 11. Among the regressors, only lipi is statistically significant. Its coefficient is approximately -0.493, and its p value is approximately 0.007. This implies that, ceteris paribus, a one-unit increase in *lipi* is associated with about a 39% decrease in expected $PM_{2.5}$, calculated as $100\exp -0.493 - 1$, approximately -38.9%. The coefficients on *lepe*, *lhdi*, and *ldensity* are not statistically different from zero at conventional levels, meaning the data provide no strong evidence that these covariates are systematically related to $PM_{2.5}$ once province and year fixed effects are controlled for in this specification.

LOPO results in Table 12 show that *lipi* is the most robust regressor: it remains statistically significant in essentially all LOPO runs with small coefficient shifts. In contrast, *lhdi* is highly sensitive in magnitude but not significant, while *ldensity* has moderate sensitivity and only occasional significance. *Lepe* is very stable in size but also consistently insignificant.

Table 10. Descriptive statistics for air quality model

	Count	Mean	Std	Min	25%	50%	75%	Max
lpm25	234.00	3.05	0.45	2.38	2.68	3.04	3.39	3.80
lepe	234.00	5.17	0.69	4.20	4.73	5.07	5.59	6.46
lhdi	234.00	0.53	0.02	0.49	0.51	0.52	0.54	0.57
ldensity	234.00	5.69	0.85	4.55	4.92	5.61	6.32	7.03
lipi	234.00	4.70	0.06	4.59	4.66	4.70	4.74	4.79

Table 11. Gamma–Log estimates for annual $PM_{2.5}$

Variable	Coef.	SE	z	p	Δ%
lepe	-0.00	0.02	-0.22	0.82	-0.46
lhdi	1.47	3.05	0.48	0.63	334.77
ldensity	1.15	0.75	1.54	0.12	216.83
lipi	-0.49	0.18	-2.70	0.00***	-38.90

Notes: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.
$\Delta\% = 100\exp\beta - 1$ is the multiplicative percent change in $\mathbb{E}PM_{2.5}$ for a one-unit increase in the regressor.
Two-way fixed effects; standard errors clustered by province

Table 12. LOPO sensitivity summary for air quality model

Variable	max $\|\Delta\|$	mean$\|\Delta\|$	Share sig. (10%)	Share sig. (5%)
lhdi	1.79	0.22	0.00	0.00
ldensity	0.32	0.06	0.10	0.02
lipi	0.09	0.01	1.00	1.00
lepe	0.01	0.00	0.00	0.00

5. Discussion

The updated estimates provide limited support for the hypotheses (H1–H3), suggesting that Vietnam's environmental protection expenditure does not translate into clear short-run improvements once province and year fixed effects are controlled for. In the air-quality model for annual $PM_{2.5}$. The coefficient on EPE is close to zero and not statistically significant, whereas IPI has a negative and statistically significant effect, with an approximate coefficient of -0.49 and a p value below 0.01. It means roughly a 39% lower expected $PM_{2.5}$ for a one-unit increase in IPI. This finding is inconsistent with the results reported in [10, 31]. The insignificant effect may be explained by the fact that the structure of environmental protection spending has not sufficiently prioritized air quality improvement. It may also reflect inefficiencies in budget implementation or the inadequacy of public expenditure relative to rising pollution levels, since spending concentrated on wastewater treatment, tree planting, or administrative activities is unlikely to generate substantial improvements in air quality.

In addition, the study period covers years during which Vietnam was affected by the COVID-19 pandemic, when public spending was largely redirected toward healthcare, social protection, labor, and employment rather than environmental objectives. Air quality indicators also temporarily improved during lockdowns due to reduced production and transportation, thereby weakening the observable relationship between environmental protection spending and air quality.

For water outcomes, average marginal effects show that population density is the only consistently significant predictor: higher density is associated with higher expected coverage of both urban clean water and industrial wastewater treatment, whereas EPE and HDI are not statistically distinguishable from zero. For land-use outcomes, the estimated marginal effects are generally small and imprecise, with only the residential share showing statistically significant but very small negative marginal effects for EPE and IPI. Agricultural, forestry, and special land shares show no robust EPE signal in this specification.

6. Conclusion

Vietnam's provincial data from 2019 to 2023 suggest that EPE does not show a clear short-term improvement in air and land outcomes once province and year effects are controlled for. The most consistent pattern is that population density remains related to outcomes across different model checks, while HDI and EPE effects are usually small, noisy, or sensitive to a few provinces. Overall, short-term improvements are more likely to appear through operational or infrastructure channels than through slow-moving outcomes such as land-use shares.

For policy, this implies three points. First, EPE should go together with stronger implementation and simple performance monitoring, especially in areas with fast, measurable outputs such as wastewater treatment and air quality monitoring. Second, because density effects look stable, combining compact urban planning with basic services and emissions control may deliver more predictable benefits than increasing spending alone. Third, better provincial data systems, consistent measurement rules including satellite indicators, and routine environmental audits would make evaluation more reliable.

For future research, longer time coverage is needed to test delayed effects of spending. Furthermore, if it becomes possible in the future to collect data on the composition of environmental protection expenditures, specifically broken down by expenditure category, more detailed impact assessments could be conducted. On the other hand, detailed spatial data and validation with ground monitoring would reduce measurement concerns. Dynamic and spatial models and more disaggregated fiscal data could also help explain persistence and spillovers across provinces.

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