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DO FISCAL INCENTIVES CURB ENVIRONMENTAL POLLUTION? EVIDENCE FROM CHINA'S ENERGY SAVING AND EMISSION REDUCTION POLICY

Zhaoyuan Chen[1*], Jiachang Liu[1], Yawen Xue[1], Shujing Zhang[1], Feiran Liu[2]

[1]School of Public Finance and Taxation, Southwestern University of Finance and Economics, China
[2]School of Accounting, Southwestern University of Finance and Economics, China

Corresponding author: Zhaoyuan Chen
qqaa2024@126.com

Abstract: This paper explores the impact of fiscal incentives on environmental pollution by employing China's Energy Saving and Emission Reduction (ESER) fiscal policy as a quasi-natural experiment. Using the STIRPAT framework and a difference-in-differences approach with city-level panel data from 2006 to 2019, we find that fiscal investment significantly reduces pollution emissions. However, the policy's effects diminish over time and are more evident in cities with greater fiscal autonomy. Mechanism analysis shows that fiscal investment enhances green innovation, highlighting its vital role in advancing environmental sustainability.

Keywords: Fiscal incentives; Environmental pollution; STIRPAT model

1. Introduction

Industrial sulfur dioxide (SO_2) emissions and industrial wastewater effluent (WW) are global concerns because they pose significant environmental and public health risks (Okereke, Ogidi, & Obasi, 2016; Zhong et al., 2020). In particular, in developing countries, rapid industrialization and insufficient pollution control measures have intensified emissions, leading to severe environmental degradation (Geng et al., 2016). Consequently, city pollution control in these regions has become crucial. As the world's largest developing country, China is grappling with severe pollution challenges (Geng et al., 2014). For example, China's SO_2 emissions are a growing concern, accounting for approximately one-fourth of global emissions (Lu et al., 2010). In addition, over the past few decades, 45% of China's major rivers have experienced severe pollution, exposing more than half of the country's 1.3 billion people to chemically and biologically contaminated water (Geng et al., 2014).

Beyond direct health and ecological risks, persistent pollution generates substantial economic and social costs by reducing labor productivity, increasing healthcare expenditures, and constraining sustainable growth. These consequences underscore the urgency of identifying effective policy instruments that can simultaneously safeguard the environment and sustain economic development.

The ESER policy is implemented with the central government allocating annual subsidies of 600 million yuan to municipalities, 500 million yuan to sub-provincial and provincial capital cities, and 400 million yuan to other cities (Xue & Chen, 2022). Additionally, the central government assesses the performance of demonstration cities and provides an additional 20% in incentive funds to those that achieve outstanding evaluation results. By leveraging the incentive effects of the transfer payment system, the policy stimulates investment, promotes institutional innovation, facilitates economic restructuring, and contributes to achieving emission reduction goals (K. Wang, Yin, He, & Wang, 2024). The policy was implemented in three phases: the first phase designated eight pilot cities, including Beijing and Shenzhen; the second and third phases, introduced in 2013 and 2014, expanded the program to an additional ten and twelve cities, respectively. Table 1 presents the three batches of demonstration cities and their corresponding pilot years. These cities are geographically distributed across eastern, central, and western China and encompass municipalities, sub-provincial cities, and ordinary prefecture-level cities, ensuring broad representativeness (Zhou & Lin, 2025).

Table 1: Three batches of demonstration cities and their corresponding pilot years

Pilot Batches	Pilot Year	City Number	City List
First Batch	2011-2013	8	Beijing, Shenzhen, Chongqing, Hangzhou, Changsha, Guiyang, Jilin, Xinyu
Second Batch	2013-2015	10	Shijiazhuang, Tangshan, Tieling, Qiqihar, Tongling, Nanping, Jingmen, Shaoguan, Dongguan, Tongchuan
Third Batch	2014-2016	12	Tianjin, Linfen, Baotou, Xuzhou, Liaocheng, Hebi, Meizhou, Nanning, Deyang, Lanzhou, Haidong, Urumqi

The ESER policy is also innovative in its design, as it incorporates competitive incentives through performance-based evaluation, encourages experimentation across diverse regions, and links fiscal transfers with broader goals of industrial upgrading and green transformation. This makes the program not only an environmental policy but also a governance innovation within China's fiscal system.

In our study, we use the ESER policy as an exogenous shock to examine the impact of fiscal incentives on pollution emissions. We designate the pilot cities from the three phases as the treatment group, with their respective pilot years serving as the policy implementation years. Using the difference-in-differences (DID) approach, we analyze city-level panel data from 2006 to 2019 to assess the effect of the ESER policy on pollution reduction. The results show that the ESER policy significantly reduces pollutant emissions, including sulfur dioxide and industrial wastewater, with the reduction effect becoming more pronounced as fiscal investment increases. Although the fiscal support period of the ESER policy lasts for three years, we are also interested in examining whether long-term reductions in pollutant emissions persist. To test the long-term effect, we exclude data from the three years of policy implementation and retain the sample after the policy ended, confirming the no existence of lasting reductions. Furthermore, we perform a heterogeneity analysis by dividing cities into high-autonomy and low-autonomy groups. Since cities with lower fiscal autonomy have a greater incentive to allow industrial emissions to boost economic growth and fiscal revenue, the empirical results indicate that cities with higher fiscal autonomy experience greater reductions in pollution levels. Additionally, the mechanism analysis reveals that the ESER policy reduces pollutant emissions by fostering green innovation. We also conduct event-study and placebo tests, which separately pass the pre-policy parallel trend test and rule out the influence of other external factors.

The structure of the paper is organized as follows: Section 2 provides a comprehensive review of the literature and outlines our contribution, Section 3 outlines the research methodology and data sources, Section 4 presents the empirical results, and Section 5 concludes the study, discussing its policy implications.

2. Literature overview

Firstly, the literature on the impact of fiscal expenditure on environmental pollution reduction remains limited. Most studies focus on the effects of fiscal pressure and environmental tax policies, such as fiscal pressure (Kong & Zhu, 2022), carbon financial markets (Gu, Zheng, Tong, & Dai, 2022), mandatory emission trading scheme (Ouyang, Fang, Cao, & Sun, 2020) and new energy demonstration city policy (Yang, Zhang, Ren, & Ran, 2021), among others. However, existing studies lack direct evidence on how fiscal investment affects pollution emissions. Our study examines the impact of fiscal expenditure policies on pollution emissions through direct fiscal environmental protection incentives. In particular, while some research has explored how environmental tax revenues are recycled into green projects, far less attention has been paid to the proactive role of fiscal transfers or subsidies as a driving force for pollution reduction. This creates an important gap, as fiscal incentives may affect local governments' behavior differently from tax-based or market-oriented instruments.

Secondly, there is ongoing debate about the effectiveness of environmental regulations in reducing emissions. Some scholars argue that environmental policies play a significant role in mitigating emissions. However, according to Hao, Deng, Lu, and Chen (2018), regulations have failed to achieve their intended goal of controlling and reducing pollution. Furthermore, some studies suggest that the impact of environmental regulations depends on external conditions (Pang, Zheng, Shi, & Zhang, 2019). Our paper contributes to this debate by examining whether environmental regulations effectively reduce pollution emissions and evaluating the effectiveness of the ESER policy.

Lastly, our paper contributes to the literature related to the ESER policy. Existing literature on ESER primarily focuses on corporate green innovation (Jin, Yang, & Chen, 2022), industrial transformation and upgrading and resident health (Yan & Li, 2023). To our knowledge, the most closely related studies to our paper is Zhou and Lin (2025), Xue and Chen (2022) and Lee, Wang, and Tang (2024), which found that the ESER policy effectively reduces electricity consumption and carbon dioxide emissions, providing evidence for emission reduction. However, our study employs SO_2 and wastewater emissions as pollution indicators, as these are major environmental pollutants that more directly impact water and air quality. By focusing on pollutants that directly harm human health and ecosystems, our study complements existing research that has emphasized carbon emissions, thereby providing a more comprehensive understanding of the ESER policy's environmental impacts.

3. Research

3.1 STIRPAT theoretical model

$T = P \times A \times T$ The STIRPAT model is widely employed to examine the relationship between environmental impact () and its key driving factors—population (), affluence (), and technology (). The model is derived from the IPAT identity (). which provides a conceptual framework for understanding how demographic, economic, and technological factors jointly determine environmental outcomes. Unlike the deterministic IPAT identity, STIRPAT introduces elasticity parameters and a stochastic error term, making it more flexible for empirical estimation. This flexibility allows researchers to test hypotheses about the relative contributions of , , and , and to extend the model by incorporating policy or institutional factors.

$Policy$ In addition, we introduce a variable to capture the effect of the ESER policy

$$\left(\frac{I}{P}\right)_{it} = a(A_{it})^{\gamma}(T_{it})^{\delta}(Policy_{it})^{\beta} \qquad (1)$$

intervention, which is specified as follows:

$Policy_{it}$ where denotes the per capita environmental impact, denotes the model constant, and , , and represent the elasticities (exponents) associated with the respective independent variables. Specifically, affluence () captures the scale of economic activity, technology () reflects the role of innovation and energy efficiency, and it is included to capture the exogenous fiscal incentives introduced by the ESER program. This extension enables us to explicitly test whether fiscal subsidies can alter the conventional population-affluence-technology relationship by stimulating green development and reducing pollution.

$$ln\left(\frac{I}{P}\right)_{it} = lna + \gamma lnA_{it} + \delta lnT_{it} + \beta Policy_{it} \tag{2}$$

By taking the natural logarithm of both sides of equation (1), we obtain equation (2):

Equation (2) thus serves as the empirical foundation for our econometric analysis, linking fiscal incentives with environmental impacts while controlling for structural drivers. This specification not only allows us to estimate the elasticity of environmental pressure with respect to affluence and technology but also isolates the policy effect in a difference-in-differences framework, thereby providing causal evidence on the role of fiscal investment in pollution reduction.

3.2 Data

We constructed a city-level panel dataset covering the period from 2006 to 2019, drawing data from the China City Statistical Yearbook, China Statistical Yearbook and the Chinese Research Data Services (CNRDS) Platform. The descriptions of the variables are provided in Table 2.

Table 2: Variable descriptions

Variables	Type	Definition
SO_2	Dependent Variable	The logarithmic form of per capita industrial sulfur dioxide emissions.
WW	Dependent Variable	The logarithmic form of per capita industrial wastewater discharge.
ln *dpergdp*	Control Variable	The logarithmic form of per capita GDP, adjusted to 2010 prices based on the CPI.
ln *dperfdi*	Control Variable	The logarithmic form of per capita actual utilized foreign direct investment (FDI) in the current year, adjusted to 2010 prices based on the CPI
ln *percollege*	Control Variable	The logarithmic form of per capita number of higher education institutions
fisauto	Heterogeneity Variable	Fiscal autonomy—calculated as the ratio of fiscal revenue to fiscal expenditure
perpatgra	Mechanism Variable	Total number of green utility model patents granted per capita
perpatapp	Mechanism Variable	Total number of green utility model patent applications per capita

Dependent variables. Following the variable selection of Liu, Wang, Zhang, Zhan, and Li (2018), we chose industrial sulfur dioxide emissions and industrial wastewater effluent as key variables to measure environmental pollution. This choice is based on the fact that industrial pollution is a major contributor to environmental degradation in China, with these pollutants being among the most significant. Due to incomplete data availability, we did not include waste soot and dust as dependent variables.

Independent variables. The core independent variable in our study is whether a city is a pilot city and the year the pilot program began. We collected the list of pilot cities and their respective start dates from the websites of the Ministry of Finance and the National Development and Reform Commission of China, as shown in Table 1.

Control variables. The control variables in our study include per capita GDP (ln *dpergdp*), the actual amount of foreign investment utilized per capita in a given year (ln *dperfdi*), and the number of higher education institutions per capita (ln *percollege*). GDP and foreign investment have been adjusted using the CPI with 2010 as the base year. Additionally, year and city dummy variables were included in the regression analysis.

Other variables. Fiscal autonomy (fisauto) is calculated as the ratio of fiscal revenue to fiscal expenditure. The patent indicators include the total number of green utility model patents granted per capita (perpatgra) and the total number of green utility model patent applications per capita (perpatapp). The share of the secondary industry is calculated based on the proportion of the value-added of the secondary industry to GDP.

3.3 Difference-in-differences approach

Based on equation (2) derived from the STIRPAT theoretical framework, we transform the model into its empirical specification:

$$Y_{it} = \rho + \beta did_{it} + \gamma X_{it} + \mu_i + v_t + \varepsilon_i \tag{3}$$

$T_{it;} l_{it} = 0$ In the above equation, and represent the city and year, respectively. The dependent variable in equation (3) includes the logarithmic form of per capita sulfur dioxide emissions (SO_2) and per capita industrial wastewater emissions (WW). In the empirical model, we use to represent in the STIRPAT framework. Specifically, if the city is designated as a demonstration city during the first, second, and third year, otherwise, . represents the control variables. accounts for city-level fixed effects, captures year-level fixed effects, and represents the standard errors clustered at the city level. In equation (3), affluence is replaced with GDP per capita in control variables (P. Wang et al., 2013), and is omitted as the policy effects are identified (Aziz et al., 2024). Given the three-year policy duration, the two-way fixed effects DID estimator may be biased after policy termination . Following and K. Wang et al. (2024), we retain data for two years post-implementation and exclude pilot cities thereafter.

3.4 Event study approach

We also estimate an event study model to test for any potential pretreatment effects of the policy. The event study model is expressed as follows:

$$Y_{it} = \alpha + \sum_{k=-5}^{2} \beta_k I(\tau_{it} = k) + \gamma X_{it} + \mu_i + v_t + \varepsilon_i \tag{4}$$

$\beta_k = 2{\cdot}5$ In this analysis, represents a series of dummy variables capturing the number of years before and after the reform's implementation in a city. Specifically, represents the exact year the policy begins, indicates five years before the policy, represents two periods after the policy, and so forth. The period six years before and earlier serves as the reference period for the policy. The estimated coefficients should be interpreted as the effect of being in a specific period, such as the first year after the policy implement, relative to six years and before prior to the announcement. This design not only allows us to test whether treated and control cities followed parallel trends before the reform but also helps to identify how the policy effect evolves in the years immediately following its introduction.

4. Discussion

4.1 Baseline results

Based on equation (3), we present the results of the ESER policy's impact on sulfur dioxide emissions and industrial wastewater discharge in Table 3. The coefficient of did variable reflects the effect of the policy shock on environmental pollution, which is our primary focus.

First, the results in columns (1) and (2) indicate that an increase in fiscal investment significantly reduces per capita SO_2 and wastewater emissions, with estimated reductions of 18.1% and 13.8%, respectively. To reduce omitted variable bias, we include city-level control variables in columns (3) and (4), which yield similar results.

Table 3. Baseline results.

Variable	(1)	(2)	(3)	(4)
	SO_2	WW	SO_2	WW
did	-0.181**	-0.138**	-0.168**	-0.134**
	(0.087)	(0.058)	(0.085)	(0.060)
ln *dpergdp*			0.318***	0.076
			(0.103)	(0.092)
ln *dperfdi*			-0.035**	-0.001
			(0.017)	(0.015)
ln *percollege*			-0.014	-0.094*
			(0.057)	(0.052)
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	3634	3634	3634	3634
R^2	0.87	0.85	0.88	0.85

Note: Standard errors (reported in parentheses) are clustered at the city level. *, ** and *** denote 0.1, 0.05 and 0.01 significance levels, respectively.

4.2 Event study

We also extend our analysis of the policy effects by plotting the event study estimates from equation (4) in Figure 1. We observe little to no significant changes in SO_2 emissions prior to the start of the pilot program in the left figure, nor do we for wastewater effluents in the right figure. However, the ESER policy has a significantly negative effect on SO_2 emissions and wastewater effluents in the implementation year and the subsequent two years.

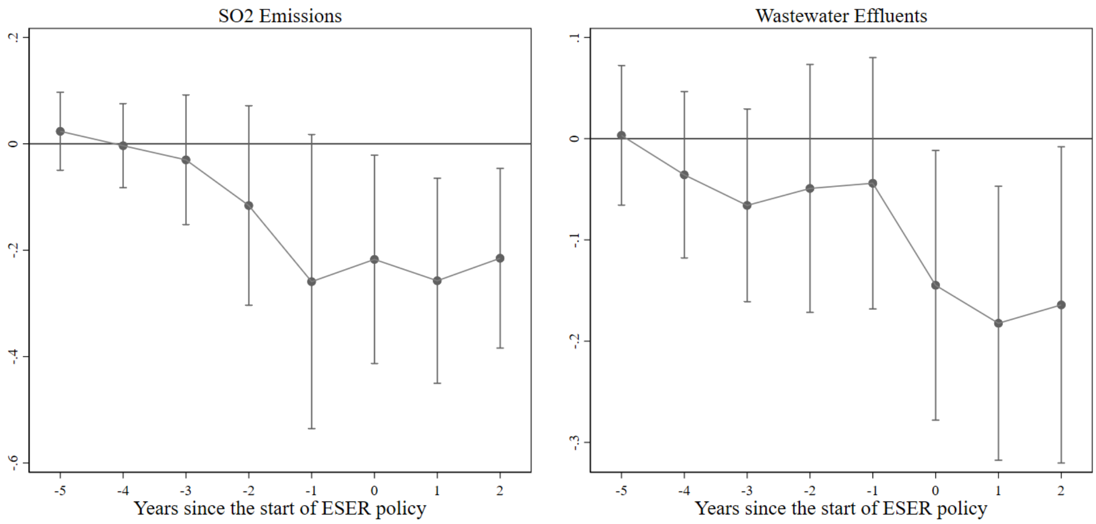

Figure 1. Results of event study.

4.3 Further analysis

Although the policy was implemented for only three years, we examine whether its effects on pollution emissions persist in the post-policy period. To this end, we exclude observations during the implementation phase and focus on the post-policy data using equation (3). Results in Table 4 (columns 1-2) suggest no significant long-term reduction in emissions.

We further explore heterogeneity in policy effects by fiscal autonomy. Based on the 2011 median, pilot cities are divided into high- and low-autonomy groups (columns 3-4 and 5-6, respectively). The policy significantly reduces emissions in high-autonomy cities but has no effect in low-autonomy ones, likely due to fiscal constraints limiting their willingness to curb emissions amid growth and revenue concerns.

Table 4. Long-run effects and heterogeneous effects fiscal autonomy.

	Long-run effects		High-autonomy		Low-autonomy	
Variable	(1)	(2)	(3)	(4)	(5)	(6)
	SO_2	WW	SO_2	WW	SO_2	WW
did	-0.174	0.012	-0.286***	-0.188**	-0.029	-0.066
	(0.15)	(0.09)	(0.11)	(0.08)	(0.11)	(0.07)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	3659	3659	3502	3502	3483	3483
R2	0.87	0.85	0.88	0.85	0.87	0.84

Note: Standard errors (reported in parentheses) are clustered at the city level. *, ** and *** denote 0.1, 0.05 and 0.01 significance levels, respectively.

In Table 5, we further examine whether the policy reduces pollution emissions through the channel of innovation. Columns (1) and (2) use, respectively, the total number of green utility model patents granted per capita (perpatgra) and the total number of green utility model patent applications per capita (perpatapp) in the current year as the dependent variables. Both estimations yield significant positive effects, indicating that the policy stimulates green innovation. In particular, the coefficients of 0.072 and 0.071 suggest that the ESER policy not only encourages more applications for green patents but also increases the likelihood of those patents being granted. This implies that fiscal investment in environmental protection fosters genuine technological progress rather than symbolic innovation activities. Overall, these results support the view that one important mechanism of pollution reduction is the promotion of green innovation, which helps improve firms' technological capacity and contributes to more sustainable environmental outcomes.

Table 5. Mechanism analysis.

	(1)	(2)
	perpatgra	perpatapp
did	0.072**	0.071**
	(0.03)	(0.03)
Controls	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes
N	3634	3634
R^2	0.57	0.57

Note: Standard errors (reported in parentheses) are clustered at the city level. *, ** and *** denote 0.1, 0.05 and 0.01 significance levels, respectively.

To further validate our empirical strategy, we conduct a placebo test by running 500 regressions using SO_2 emissions and wastewater discharge (WW) as dependent variables, as shown in Figure 2. In each iteration, we randomly assign the same number of cities and years as the actual ESER pilot cities and policy years, thereby constructing a pseudo-policy. Under this random assignment, the coefficient of did is expected to be zero if our results are not driven by spurious correlations.

β Figure 2 plots the distribution of the estimated coefficients from these placebo regressions. The vertical dashed lines represent the treatment effect estimates from Columns (3) and (4) of Table 3. For both dependent variables, the distribution of is approximately normal and centered around zero, indicating that the randomly generated reform variable does not produce any significant effect. This provides strong support for the credibility of our identification strategy, as the actual policy effect clearly stands out from the placebo distribution.

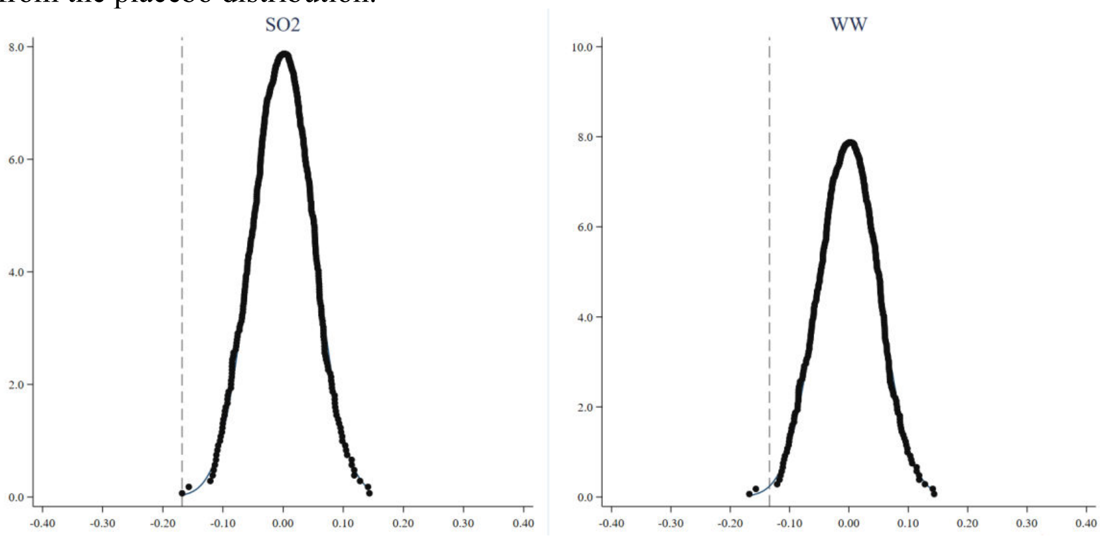

Figure 2. Placebo Test.

Note: Figure 2 reports the results of 500 placebo regressions where the ESER policy was randomly reassigned across cities and years.

5 Conclusions

This paper investigates the effects of China's Energy Saving and Emission Reduction fiscal demonstration city policy on environmental pollution. By combining the STIRPAT framework with a difference-in-differences empirical strategy and city-level panel data from 2006 to 2019, our study provides robust evidence that fiscal incentives can play a significant role in reducing pollution emissions, albeit with some limitations.

Our baseline results indicate that fiscal subsidies under the ESER program significantly reduced industrial sulfur dioxide and wastewater emissions in pilot cities during the implementation period. The event study analysis further confirms that these reductions are directly attributable to the policy rather than to pre-existing trends, thus reinforcing the credibility of the causal inference. However, the long-term analysis shows that the policy's effects diminish once the fiscal support ends, suggesting that without continuous incentives or structural institutional reforms, the sustainability of emission reductions is limited.

The heterogeneity analysis highlights that the effectiveness of fiscal incentives varies with local fiscal autonomy. Cities with higher fiscal autonomy experienced stronger pollution reductions, as they possessed greater capacity and flexibility to allocate resources toward environmental governance. In contrast, cities with weaker fiscal autonomy showed little or no policy effect, reflecting the constraints imposed by fiscal dependence and revenue pressures. This finding suggests that fiscal decentralization and local financial empowerment are crucial to enhancing the environmental effectiveness of national fiscal policies.

Mechanism analysis provides additional insights, showing that the ESER policy promotes green innovation, as measured by both green patent applications and grants. This indicates that fiscal incentives not only directly reduce emissions but also generate indirect benefits through fostering technological progress. Green innovation, in turn, strengthens the foundation for long-term sustainable development by enabling cleaner production processes and more efficient resource utilization.

Taken together, the findings of this paper contribute to the broader debate on the role of fiscal policy in environmental governance. While fiscal investment proves effective in reducing pollution during the short term, its impact is neither universal nor enduring without supporting institutional reforms, continuous funding mechanisms, and incentives that encourage local initiative. Therefore, to maximize the effectiveness of fiscal policies in achieving environmental objectives, policymakers should: (1) increase targeted fiscal transfers to heavily polluted regions; (2) design differentiated incentive schemes that account for cities' fiscal capacity and governance efficiency; (3) strengthen institutional arrangements to ensure the persistence of emission reductions beyond the policy cycle; and (4) actively promote innovation ecosystems that combine fiscal support with research, industry collaboration, and technological diffusion.

In conclusion, fiscal incentives such as the ESER demonstration city program can serve as a powerful tool for pollution reduction and environmental sustainability in developing countries. However, their long-term success depends on integrating financial support with institutional reforms, innovation promotion, and enhanced fiscal autonomy at the local level. These insights not only enrich the literature on fiscal policy and environmental regulation but also provide practical implications for policymakers seeking to balance economic growth with ecological sustainability.

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