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Research on the Impact of Fiscal Decentralization on Governance Performance of Air Pollution—Empirical Evidence of 30 Provinces from China

Wenjian Luo [1,2,*] and Yujie Liu [1]

[1] School of Public Policy and Administration, Nanchang University, Nanchang 330031, China
[2] Center for Anti-Corruption Studies, Nanchang University, Nanchang 330031, China
* Correspondence: wjluo@ncu.edu.cn

Abstract: Air pollution governance is of great benefit to future generations, and its steady performance improvement is inextricably linked to the fiscal relationships between the central and local governments in China's decentralization context. Based on the provincial panel data from 2011 to 2019, this paper constructs a comprehensive index of air pollution governance performance using the entropy method. Then, the relationship between fiscal decentralization and governance performance of air pollution is measured using a two-way fixed effects model. The results show that the increase in fiscal decentralization is not conducive to the improvement in governance performance of air pollution. Moreover, fiscal decentralization weakens the positive impact of pollution control investment on enhancing governance performance of air pollution while easing the negative impact of local government capital attraction competition on enhancing governance performance of air pollution. In terms of regional level, fiscal decentralization in northern and inland regions significantly negatively impacts air pollution governance performance. However, the above effects are not significant in the southern and coastal regions. The policy implications of the above findings are as follows: first, the central government ought to optimize the financial decentralization system and promote multiple performance assessments. Second, it is essential to adjust the structure of fiscal spending and promote competitive partnerships among local governments. Third, emphasis should be placed on collaborative governance of key regions while developing an effective incentive mechanism.

Keywords: fiscal decentralization; air pollution; government action; governance performance

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1. Introduction

In the process of industrialization, influenced by the development pattern of "treatment after pollution", China's economy has been soaring. In contrast, environmental pollution, especially the problem of air pollution, is becoming increasingly prominent. As an unavoidable environmental exposure, air pollution directly affects public health, causing cognitive and cardiovascular diseases [1,2]. Moreover, it harms sustainable economic development and social civilization [3,4]. The public generally gets nervous and worried when regards haze pollution nowadays. "Breathing air together, sharing fate together" has become a slogan strongly called for by all sectors of society. The Communist Party of China has also made continuous efforts to enhance the strategic height of air pollution governance work, such as integrating the goals of winning the battle against pollution and eliminating heavily polluted weather into the 14th Five-Year Plan. Furthermore, Premier Li Keqiang emphasized the importance of air pollution governance in his government work report for the third consecutive year. He pointed out that we must consolidate the achievements of the Three-Year Action Plan to Win the Battle of Blue Sky, and pollution governance should be legal, scientific, and precise. The Ministry of Ecology and Environment and seven other departments jointly issued the "Implementation Plan for Synergistic Carbon Reduction and Efficiency Improvement" in June 2022. As one of the important documents of the

carbon neutrality policy system, the implementation plan provides action guidance on air pollution prevention and control goals. It can be seen that the central government has declared war on air pollution with unprecedented strength, and thus the quality of the air environment continues to improve. However, there is still a mismatch between the speed of improvement of the air environment and the needs of the citizens, and the prevention of air pollution has entered a bottleneck. The statistics in the "China Ecological Environment Bulletin (2020)" show that the quality of China's air environment is constantly improving, but there are still areas that need urgent improvement. For example, weather with PM2.5 as the primary pollutant accounts for more than half of the total in 2020, and less than 60% of cities meet air quality standards. According to the data published by the 2022 Global Environmental Performance Index (EPI), China ranked 160th in the EPI and 157th in the Air Quality Index among the 180 countries evaluated. Compared with 2018, this ranking has improved slightly but remains at the back of the pack overall. The national air pollution situation is still grim and has a long way to go. Against this backdrop, taking action to clean the air is a top priority.

Identifying the causes of air pollution is essential to improving and controlling the haze problem. In the context of the Chinese decentralization mechanism, the influence of institutional factors on air pollution governance cannot be underestimated. Additionally, fiscal decentralization, as an essential part of the decentralization system, is naturally and deeply related to local governance performance of air pollution [5]. Specifically, air pollution governance follows the administrative contracting model, which is characterized by the central government taking the lead, the provincial level coordinating, and finally, the grassroots level implementing [6]. As a result, local governments have relatively full flexibility in the funding arrangements for air pollution governance. On the one hand, this decentralization trend fully motivates local governments to develop their economies, thus promoting competition among them. Inspired by both political "promotion tournaments" and the need for self-interest, local officials are inclined to invest resources in projects that will produce significant economic results in the short term. In contrast, the economic benefits brought by air pollution governance have long payback cycles, often giving way to economic development goals in the governance process. Sometimes it even becomes a sacrificial object [7]. On the other hand, local governments, as the principal agent of the central government, are responsible for implementing the central environmental policies and providing environmental public goods to their residents. Especially in some periods of political sensitivity, local governments tend to adopt some expedient measures to create a temporary "political blue sky [8]." This has also become the best example of the interaction between the central and local governments in the context of decentralization.

The purpose of this paper is to answer the following questions. Does fiscal decentralization impact governance performance of air pollution? If so, how does this influence differ in the horizontal and vertical dimensions of fiscal decentralization? What is the inherent logical path? Addressing the above questions is helpful for properly understanding the relationship between the fiscal decentralization system and the governance performance of air pollution. It is also a useful supplement to the existing analytical framework of local environmental governance. Meanwhile, it is important to further the financial system reform and promote the scientific and normalization of air pollution governance. The rest of this paper is organized as follows. The next section discusses the existing literature on decentralization and pollution governance. Based on this, the research hypothesis of this paper is proposed. Section 3 introduces the empirical methods, models, and data. Section 4 provides the empirical results. Section 5 is a discussion section that analyzes the relationship between fiscal decentralization and air pollution governance performance under different action directions and in various regions. The final section draws the conclusion and implications.

2. Theory and Hypothesis

2.1. Literature Review

Pollution is the product of a combination of many factors. As one of the key institutional factors, fiscal decentralization under political centralization cannot be ignored. Existing studies have explored various aspects of the relationship between fiscal decentralization and pollution. It can be broadly divided into three types of views: inhibition theory, promotion theory, and nonlinear theory. Among them, the mainstream disincentive theory believes that fiscal decentralization will reduce the efficiency of pollution governance [9,10]. To consider the problems of incentive alienation and insufficient constraints brought about by fiscal decentralization, local governments may relax environmental regulations for economic development. This allows public funds to flow to jurisdictions with less regulation, thus indirectly inducing environmental degradation. A large number of empirical arguments support this conclusion. Using a combination of empirical models, scholars have confirmed that an increase in the degree of fiscal decentralization significantly reduces the governance performance of environmental pollution. Commonly used models include the Spatial Durbin Model [11,12], the fixed effect model [5,13], and the DEA (Data Envelopment Analysis) method [14]. Distinguishing from the views mentioned above, some scholars focus on the positive significance of fiscal decentralization in enhancing the efficiency of public goods supply in the environmental field and then put forward the claim that fiscal decentralization benefits pollution governance [15]. The early decentralists, represented by Tiebout, believed that residents could "vote by foot" to motivate the government to provide public goods that meet their preferences [16]. Thus, decentralization can contribute to the improvement of environmental quality. Based on this, environmental federalist scholars, represented by Oates, have studied more deeply [17,18]. They further point out that local governments have more information advantages than the central government. Therefore, decentralization allows local governments to develop more appropriate environmental policies and thus more efficiently meet the needs of residents for environmental public goods. Some empirical studies also support the contribution of fiscal decentralization to pollution governance. Millimet used the Propensity Score Matching (PSM) method to empirically test the "race to the top" phenomenon in a decentralized environment [19]. Sigman's study of water pollution around the world found that decentralization of the federal state is beneficial to the environment [20]. Using a system Generalized method of moments (GMM) estimation model, He found that fiscal decentralization has a significant positive impact on promoting environmental protection [21]. In addition, a small group of scholars argue that fiscal decentralization and pollution are not simply linearly related. They usually refine fiscal decentralization [22,23] and environmental pollutants [24]. In addition, this group of scholars focuses on examining the threshold effects of dynamic variability factors such as economic growth rate [25] and government innovation preferences [26]. In terms of findings, they found an inverted "U" shaped correlation between fiscal decentralization and environmental pollution [27]. Therefore, differential treatment measures should be adopted for different types of pollutants.

Studies on air pollution under Chinese-style fiscal decentralization are still in the initial stage. Most of them put fiscal decentralization and environmental pollution under the same research framework. Only a few research perspectives focus on the niche area of air pollution governance performance. Such studies mainly focus on efficiency evaluation using econometric instruments. In terms of the selection of research indicators, most of the existing studies adopt a single measure, such as CO_2 emissions [28], SO_2 emissions [29], PM10 concentrations [30], PM2.5 concentrations [31,32] and carbon emissions [33] to measure the severity of air pollution. The common problem with such indicators is that a single pollution indicator does not fully reflect the complete picture of the atmospheric conditions and may overestimate or underestimate the air pollution governance problem [34].

To sum up, domestic and foreign scholars have made a lot of rich and valuable thoughts on clarifying the causal relationship between fiscal decentralization and pollution. Most of them have used quantitative data to verify the relationship between the

two. However, relatively few studies have focused on atmospheric pollution. In the only empirical literature, the relationship between fiscal decentralization and air pollution is still controversial due to the different research methods, sample selection, and indicator construction. Therefore, based on the panel data of 30 provinces in China (Tibet is excluded because of its unique situation) for the past 9 years, this paper constructs a composite index of air pollution governance performance by entropy method. Subsequently, examining the impact of fiscal decentralization on air pollution governance performance directly and indirectly. We try to respond to the controversies that exist in the relationship between the two. Compared with the existing studies, this paper makes the following marginal contributions: on the one hand, the research content is different from the economic output perspective, such as urbanization level, industrial structure, and industrial agglomeration. From the perspective of Chinese decentralization system research, this paper empirically tests the micro-level impact of fiscal decentralization on air pollution governance performance. The key is to reveal the extent of its impact and transmission mechanism. On the other hand, the selection of indicators differs from existing studies. Instead of single indicators such as PM2.5, PM10 and SO_2, this paper uses the entropy method to construct a comprehensive index of air pollution governance performance. We include three major pollutants (SO_2, NO_X, Smoke and Dust) into the analysis framework at the same time to assess the current status of China's air pollution governance performance more objectively.

2.2. Formulation of Hypothesis

(1) Fiscal decentralization and governance performance of air pollution

The classical theory of decentralization proposes the theory of "voting by foot [16]". Namely, residents tend to migrate to jurisdictions with higher quality public services. In order to attract more political votes, local officials are incentivized to provide higher quality public services, and therefore jurisdictions with higher decentralization have better environmental governance. However, the theory has several strict presuppositions: first, symmetry of information, meaning that citizens can evaluate government actions and express their preferences accurately. Second, residents have a high degree of freedom of movement within their jurisdictions.

In the Chinese context, the above points are not well adapted. First, the behavior of local governments in China is less constrained by residents and more incentivized by the political assessment goals of higher levels of government. Second, the existing household registration system also weakens the willingness of residents to "vote by foot". Since employment, education, medical care, and other social benefits are closely related to the household registration system, and the "voting by foot" mechanism lacks adequate operating conditions. In practice, due to the significant negative externalities of air pollution, its management often involves cross-regional collaboration. Nevertheless, local governments tend to take a free ride to the neighboring areas in order to maximize their interests. This has led to the "Tragedy of the commons" in the process of air pollution management. According to the above analysis, we put forward our first hypothesis.

Hypothesis 1. *The increase in the degree of fiscal decentralization is not conducive to the improvement of air pollution governance performance.*

(2) Vertical compromise: weakness in pollution control

Under the Chinese-style political centralization, local governments are subject to central government management. Since the reform of the tax system in China in 1994, the financial power of the central government has been continuously strengthened. In opposition, local governments are relatively weak in vertical tax competition. The sinking of responsibilities and raising financial resources have led to the imbalance between the local government's financial power and its power of affairs. That is, a vertical fiscal imbalance is generated [35]. In the face of the central government's environmental protection policy requirements, relying on a "small financial horse" to pull a "big expenditure cart" will easily

result in financial weakness at the local government level. This can lead to uncontrolled fiscal spending. As a result, local governments implement the relevant policy requirements but use the system's flexibility to compensate for losses, such as environmental deregulation, innovative fiscal revenue, and so on. Influenced by the mechanism of promoting officials based on GDP performance, local governments tend to adjust the fiscal expenditure structure to achieve political promotion. Public funds flow to projects with quick results in the short term, such as increasing productive expenditures. Thus, the financial supply of environmental pollution governance is neglected, which distorts the supply structure to "emphasizing economic construction and neglecting pollution control" [36]. In this process, local governments are more passive in air pollution governance, thus weakening the governance performance of air pollution in their jurisdiction. The above analysis of the existing literature leads to our second hypothesis.

Hypothesis 2a. *The higher the local pollution control investment, the higher the air pollution governance performance.*

Hypothesis 2b. *Fiscal decentralization will weaken the positive effect of pollution control investment on air pollution governance performance.*

(3) Horizontal competition: incentives for pollution behavior

As the demand for career promotion of officials rises in political assessment tournaments, the pollution caused by the aggravation of competition among local governments continues to come to the fore. Due to the significant differences in natural resource conditions and different levels of economic development, developed regions can obtain more fiscal revenue with the same level of tax effort. This further widens the economic gap between local governments, namely, creating a horizontal fiscal imbalance [6]. To intensify the competition for tax sources and enhance the attractiveness of their jurisdictions, local governments compete to relax environmental regulations, imitate the tax incentives of neighboring or other regions, and reduce the threshold of enterprise entry to attract more capital. In the increasingly fierce competition for investment in each region, some short-cycle, polluting enterprises moved into the local area. This makes the gap between the rate of economic growth and the rate of deterioration of the atmosphere in the jurisdiction continue to widen. The goal of "keeping the blue sky" has given way to "keeping economic growth" to a certain extent, thus aggravating air pollution. Based on the above analysis, we put forward our third hypothesis and an overall research framework (Figure 1).

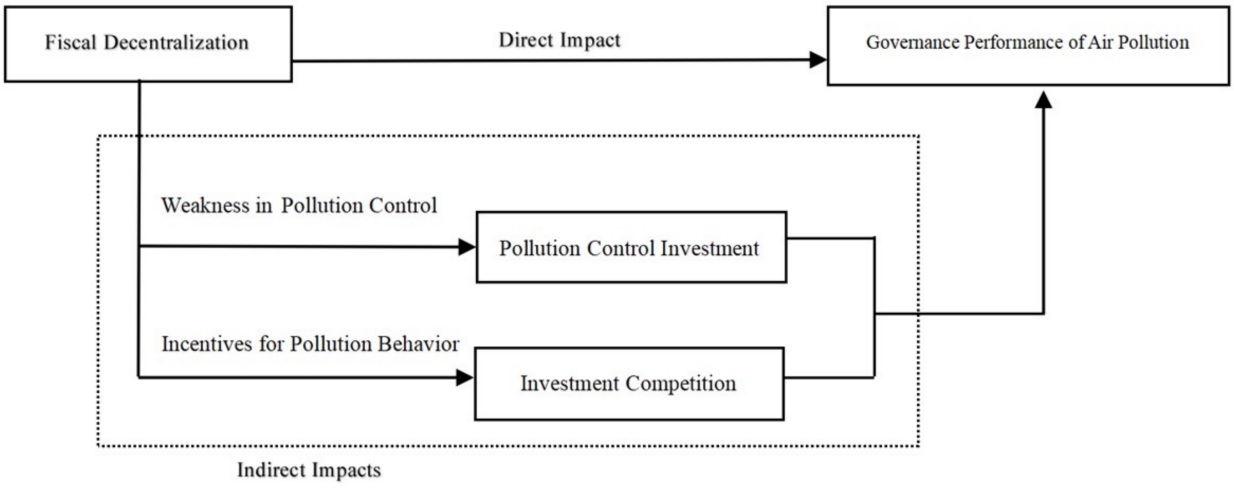

Figure 1. A path diagram of fiscal decentralization affecting governance performance of air pollution. Source: This image was constructed by the author.

Hypothesis 3a. *The more intense competition among local governments to attract investment, the lower the air pollution governance performance.*

Hypothesis 3b. *Fiscal decentralization will enhance the negative effect of local government competition for capital attraction on air pollution governance performance.*

3. Research Design

3.1. Research Sample and Data Sources

Since the 12th Five-Year Plan formally includes NO_X emissions as a key indicator for government evaluation, the data can only be obtained from statistical yearbooks after that. In addition, due to the lack of sample data required for the study, the observation year interval is determined as 2011 to 2019. The observations were made in 30 provinces, municipalities, and autonomous regions. In addition, the original data of the variables were obtained from the China Environmental Statistical Yearbook, the China Statistical Yearbook, the Finance Yearbook of China, the National Bureau of Statistics, and the China Economic Network.

3.2. Variable Selection and Description

(1) Air pollution governance performance

Smoke and dust, sulfur dioxide (SO_2) and nitrogen oxide (NO_X) are essential components of air pollutants and binding indicators for government assessment. According to previous studies [34,37], this paper uses the entropy method to construct a comprehensive index of air pollution governance performance for each province. By constructing composite index weights, this method can measure the probability that the system is in many different states [38], thus avoiding the bias of single pollutant indexes and restoring the full picture of air pollution governance performance more effectively. The original data in this paper are the emissions of Smoke and Dust, NO_X, and SO_2 in industrial waste gases, all from the China Environmental Statistical Yearbook of previous years. All the pollution emission data are expressed per capita to exclude the influence of population size. Due to the relatively light mass of air pollutants, the paper uses 10,000 per capita emissions (unit: tons per 10,000 people). The specific steps are as follows.

First, all the above pollutant emission data were dimensionless to eliminate the influence of physical quantities. We adopt the negative indicator for calculation (the smaller the value, the better the indicator).

$$x'_{ij} = \frac{M_j - x_{ij}}{M_j - m_j} \tag{1}$$

where i represents the year, j represents the pollution index, M_j and m_j represent the maximum and minimum values of the j-th pollution index, and x'_{ij} represents the assigned value after dimensionless processing. Since some data after dimensionless processing may be zero or negative, and the entropy method process involves the processing of logarithms, they cannot be used directly. Therefore, it is necessary to translate the data.

$$S_{ij} = x'_{ij} + E \tag{2}$$

where S_{ij} represents the value after shifting, and E represents the leveling magnitude. Then, the characteristic weight or contribution of the j-th pollution indicator (p_{ij}) is calculated.

$$p_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{3}$$

Then, calculate the entropy value (e_j) of the j-th indicator to derive its entropy weight (W_j).

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \ , \ 0 \le e_j \le 1 \tag{4}$$

$$W_j = \frac{1 - e_j}{\sum_{i=1}^{m}(1 - e_j)} \quad , j = 1, 2, 3 \cdots m \tag{5}$$

Finally, the composite index y_{ij} of air pollution governance performance in the year i is calculated (see Table 1 for details). A larger value of y_{ij} indicates a better air pollution governance performance of region j.

Table 1. Air pollution governance performance composite index table. (2011–2019).

Region	2019	2018	2017	2016	2015	2014	2013	2012	2011
Beijing	0.00419	0.00415	0.00386	0.00477	0.00494	0.00625	0.00530	0.00511	0.00470
Tianjin	0.00383	0.00381	0.00356	0.00411	0.00421	0.00511	0.00450	0.00435	0.00396
Hebei	0.00293	0.00279	0.00264	0.00273	0.00321	0.00361	0.00341	0.00330	0.00298
Shanxi	0.00244	0.00226	0.00200	0.00210	0.00150	0.00136	0.00191	0.00158	0.00136
Inner Mongolia	0.00029	0.00051	0.00073	0.00102	0.00076	0.00041	0.00056	0.00040	0.00070
Liaoning	0.00212	0.00211	0.00223	0.00289	0.00288	0.00331	0.00348	0.00321	0.00303
Jilin	0.00327	0.00334	0.00269	0.00371	0.00355	0.00434	0.00407	0.00410	0.00332
Heilongjiang	0.00303	0.00295	0.00263	0.00317	0.00358	0.00408	0.00351	0.00337	0.00328
Shanghai	0.00402	0.00401	0.00363	0.00444	0.00453	0.00570	0.00498	0.00481	0.00438
Jiangsu	0.00323	0.00316	0.00308	0.00379	0.00422	0.00521	0.00463	0.00454	0.00408
Zhejiang	0.00382	0.00376	0.00349	0.00438	0.00443	0.00555	0.00476	0.00472	0.00423
Anhui	0.00335	0.00339	0.00319	0.00417	0.00429	0.00524	0.00472	0.00450	0.00417
Fujian	0.00330	0.00339	0.00335	0.00420	0.00431	0.00536	0.00474	0.00461	0.00429
Jiangxi	0.00323	0.00315	0.00296	0.00392	0.00411	0.00522	0.00457	0.00443	0.00402
Shandong	0.00332	0.00331	0.00304	0.00340	0.00388	0.00480	0.00442	0.00428	0.00385
Henan	0.00393	0.00387	0.00345	0.00420	0.00413	0.00520	0.00455	0.00447	0.00404
Hubei	0.00378	0.00376	0.00343	0.00430	0.00439	0.00545	0.00480	0.00467	0.00430
Hunan	0.00373	0.00361	0.00340	0.00438	0.00449	0.00563	0.00492	0.00481	0.00437
Guangdong	0.00384	0.00379	0.00357	0.00442	0.00473	0.00594	0.00511	0.00499	0.00457
Guangxi	0.00357	0.00356	0.00337	0.00431	0.00444	0.00549	0.00481	0.00465	0.00431
Hainan	0.00404	0.00405	0.00358	0.00455	0.00486	0.00618	0.00532	0.00520	0.00481
Chongqing	0.00380	0.00370	0.00337	0.00419	0.00417	0.00529	0.00453	0.00443	0.00405
Sichuan	0.00383	0.00381	0.00345	0.00443	0.00461	0.00583	0.00507	0.00494	0.00445
Guizhou	0.00347	0.00309	0.00262	0.00346	0.00384	0.00469	0.00402	0.00392	0.00354
Yunnan	0.00334	0.00331	0.00315	0.00385	0.00434	0.00541	0.00451	0.00437	0.00405
Shaanxi	0.00335	0.00333	0.00302	0.00376	0.00342	0.00402	0.00365	0.00366	0.00334
Gansu	0.00293	0.00284	0.00277	0.00373	0.00365	0.00453	0.00415	0.00410	0.00364
Qinghai	0.00245	0.00234	0.00208	0.00183	0.00164	0.00170	0.00213	0.00222	0.00238
Ningxia	0.00043	0.00031	0.00035	0.00000	0.00043	0.00048	0.00000	0.00025	0.00000
Xinjiang	0.00202	0.00190	0.00159	0.00154	0.00213	0.00161	0.00129	0.00142	0.00204

Source: Compiled by the author, statistics do not include Tibetan areas.

Table 1 shows that the overall fluctuation of air pollution governance performance in the vast majority of regions in China from 2011 to 2019 is not significant and peaked in 2014. In terms of sub-regions, compared to the northern areas, the southern regions generally ranked higher and showed a more outstanding governance performance. In addition, Beijing ranked the highest among all the sample regions. It has dramatically improved air quality in recent years, and its experience in controlling pollution benefits other areas.

(2) Fiscal decentralization degree

The existing fiscal decentralization indicators can be divided into three categories: expenditure decentralization, revenue decentralization, and financial freedom. Among them, expenditure decentralization can better measure the adequacy of local disposable financial resources or the autonomy of local government fiscal expenditures. Referring to Zheng et al. [39] and Zhang et al. [40], we adopt the ratio of local expenditures to central expenditures to measure the degree of decentralization. In addition, we per capita the decentralized indicators to eliminate the influence of population size.

(3) Pollution control investment

Pollution governance requires a lot of financial resources, and the size of pollution control investment also reflects the local government's commitment and attention to improving environmental quality. Comprehensive findings from relevant scholars [41,42] show that pollution control investment can significantly reduce pollution. The air environment has unique characteristics compared to the water and land environment. Thus, this paper adopts the ratio of industrial pollution control investment (exhaust gas) to GDP for each region to measure the pollution control investment. This method provides a more intuitive picture of the impact of government spending structure bias on air pollution governance performance.

(4) Local government capital attraction competition

Investment promotion is a specific manifestation of local government competition [31]. In order to attract foreign investment, local governments compete to relax the environmental standards, thus aggravating air pollution in their jurisdictions. Following the previous literature [43], this paper adopts the total import and export of foreign-invested enterprises to measure the local government capital attraction competition. It is converted into RMB based on the annual average exchange rate of RMB to USD for the year, and the exchange rate is obtained from the website of the National Bureau of Statistics.

(5) Control variables

Variable description and its calculation method are shown in Table 2.

Degree of economic development (GDP). In different stages of economic development, the air pollution situation and its management concept will change accordingly. In line with this, the air pollution management behavior will also be adjusted adaptively. Therefore, it is necessary to include the degree of regional economic development in the observation factors. This paper adopts the per capita GDP for calculation according to the previous literature [5,21].

Transportation intensity (Road). During rapid industrialization, the air pollution from transportation, especially exhaust pollution, cannot be ignored. Inadequate development of urban roads compared to the rapid growth of vehicles brings the problem of traffic congestion. This can lead to insufficient fuel combustion in vehicles and exhaust emissions containing 2–3 times more pollutants than usual [44]. Referring to Liu [38], this paper adopts the urban road space per capita for calculation.

Population density (Popuden). The more densely populated an area is, the more resources it consumes and the more pollution it emits. At the same time, as public awareness of environmental protection has increased in recent years, the increase in population may lead to a further improvement in air pollution governance performance. Therefore, it is difficult to determine the direction of the coefficient between the two. Referring to Zou et al. [45], this paper adopts the ratio of the total local population at the end of the year to the area of the administrative region for calculation.

Technology level (Tech). Generally speaking, science and technology not only help enterprises reduce pollutant emissions but also make the government's pollution control actions more efficient. Therefore, scientific and technological progress is conducive to improving air pollution governance performance. Referring to Cai et al. [13], this paper adopts the ratio of science and technology expenditure to local public finance expenditure for calculation.

Table 2. Variable definitions.

	Variables	Symbol	Definition and Source
Dependent variable	Air pollution governance performance	*Pollution*	Entropy weights of NO_X, Smoke and Dust, SO_2 [1]
Explanatory variables	Fiscal decentralization	*DEC*	Local per capita fiscal expenditure/ Central-level per capita fiscal expenditure [2,3]
	Pollution control investment	*Invest*	Industrial pollution control (exhaust gas) investment/GDP [4]
	Local government capital attraction competition	*FDI*	Total import and export of foreign-invested enterprises [2,5]
Control variables	Economic development	*GDP*	Local GDP per capita [2]
	Population density	*Popuden*	Local year-end population/administrative area [2]
	Transportation intensity	*Road*	Urban road area per capita [2]
	Technology level	*Tech*	Science and technology expenditure/local budget expenditure [2]

Note: Data sources are simplified as follows: [1]. China Environment Statistical Yearbook; [2]. China Statistical Yearbook; [3]. The Finance Yearbook of China; [4]. The China Economic Net; [5]. The National Bureau of Statistics.

3.3. Model Establishment

Based on the above analysis, further panel models need to be constructed for examination. Due to geographic, political, and historical factors, there is a non-negligible individual heterogeneity among provinces and even cities in China. The fixed-effects model is useful for reducing the heterogeneity bias brought by individual differences. Following the previous literature [5,39,46], this paper constructs a base model I to examine the direct impact of fiscal decentralization on governance performance of air pollution. In addition, the instrumental variables approach is used to overcome the endogeneity problem. Namely, we substitute the lagged one-period data of air pollution governance performance into the panel data model.

$$Pollution_{it} = \alpha_0 + \alpha_1 L.Pollution_{it-1} + \alpha_2 FD_{it} + \alpha_3 C_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (6)$$

where i represents the region and t represents the year, α_0 represents the constant term, *Pollution* represents the governance performance of air pollution, *FD* represents the variable of fiscal decentralization, $L.Pollution_{it-1}$ represents the variable of lagging one-period air pollution governance performance, C represents a series of control variables, γ_i represents the regional fixed effect, δ_t represents the time fixed effect, ε_{it} represents the random disturbance term.

Based on the above model, an extended model II is established by incorporating the interaction term between fiscal decentralization and other explanatory variables, aiming to examine the indirect effects of fiscal decentralization on air pollution governance performance.

$$Pollution_{it} = \alpha_0 + \alpha_1 Pollution_{it-1} + \alpha_2 FD_{it} + \alpha_3 X_{it} + \alpha_4 X_{it} * FD_{it} + \alpha_5 C_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (7)$$

where X_{it} represents the pollution control investment or the local government capital attraction competition, $X_{it} * FD_{it}$ represents the interaction term between pollution control investment or local government capital attraction competition and fiscal decentralization.

4. Empirical Results

4.1. Descriptive Statistics

First, Table 3 shows the results of descriptive statistics for each variable. It can be seen that the mean value of local fiscal expenditure decentralization is 6.797, and the standard deviation is 2.772, which reflects that the degree of consistency in expenditure decentralization among regions in China is low and the variation is large. The mean value of local government capital attraction competition is 1876.629 with a standard deviation of

5431.615, reflecting that there are significant differences in the capital attraction ability of various local governments in China. In addition, most variables are generally consistent with the existing literature.

Table 3. Summary statistics.

Variable	N	Mean	Std	Median
Pollution	270	0.004	0.001	0.004
DEC	270	6.797	2.772	5.853
GDP	270	5.435	2.645	4.704
Road	270	15.592	4.686	15.120
Popuden	270	0.047	0.07	0.029
Tech	270	2.064	1.447	1.362
Invest	270	0.078	0.008	0.054
FDI	270	1876.629	5431.615	76.799

Then, the problem of multicollinearity of the variables is tested. The results show that the Vif (variance inflation factor) of the main variables is below 4 during the sample observation period. This indicates strong independence among the variables and is suitable for further dynamic effects panel regression analysis.

4.2. Baseline Regression Analysis

In this paper, we use STATA 16.0 to perform regression tests on panel data and adopt the normalization method to dimensionless the raw data. Normalization is an optimal data processing method that can eliminate the difference in magnitude between variables while retaining the information of variance within variables and can also enhance the model fitting effect [47].

The Hausman test first judged the applicability of FE and RE models. From the results of the Hausman test, the original hypothesis is rejected, indicating significant individual differences in air pollution governance performance and fiscal decentralization among the study samples. Therefore, the fixed effects model (FE) was finally selected. Column (1) in Table 4 shows the direct effect of fiscal decentralization on air pollution governance performance, while columns (2) and (3) show the effect of pollution control investment and its interaction term with fiscal decentralization, and local government capital attraction competition and its interaction term with fiscal decentralization on air pollution governance performance respectively.

Table 4. Impact of fiscal decentralization on governance performance of air pollution.

Variables	FE	FE	FE
	Model 1	Model 2	Model 3
L. pollution	0.506 ***	0.413 ***	0.497 ***
	(0.069)	(0.094)	(0.070)
DEC	–0.258 **	–0.166 *	–0.303 ***
	(0.098)	(0.094)	(0.105)
Road	0.216 *	0.212 **	0.215 *
	(0.106)	(0.103)	(0.107)
GDP	–0.046 *	–0.053 **	–0.047
	(0.026)	(0.025)	(0.031)
Popuden	0.226 *	0.269 **	0.224 *
	(0.116)	(0.110)	(0.119)
Tech	–0.037	–0.049 *	–0.015
	(0.030)	(0.028)	(0.038)
Invest		0.053 **	
		(0.024)	
Inter1		–15.935 ***	
		(4.475)	

Table 4. *Cont.*

Variables	FE	FE	FE
	Model 1	**Model 2**	**Model 3**
FDI			–0.012 **
			(0.006)
Inter2			2.416 **
			(0.896)
Constant	0.002 **	0.002 **	0.002 ***
	(0.001)	(0.001)	(0.001)
N	240	240	240
R^2	0.812	0.829	0.816

Notes: The standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

As can be seen from Table 4, the R^2 of both the baseline and extended models are above 0.8, indicating a strong fit of the model.

Column (1) demonstrates that the correlation coefficients between fiscal decentralization and air pollution governance performance are negative and have an inverse relationship. Specifically, each unit increase in the level of fiscal decentralization decreases air pollution control performance by 0.258 units, which is consistent with the original Hypothesis 1.

Column (2) shows the relationship between fiscal decentralization, pollution control investment, and the interaction term between the two and air pollution governance performance. The results show that the estimated coefficient of pollution control investment is significantly positive at the 5% level, indicating that pollution control investment can improve the governance performance of air pollution, which is consistent with the original Hypothesis 2a. The coefficient of the interaction term (Inter1) between fiscal decentralization and pollution control investment is significantly negative. It indicates that fiscal decentralization weakens the positive effect of pollution control investment on the governance performance of air pollution, which is consistent with the original Hypothesis 2b.

Column (3) of the table shows the relationship between fiscal decentralization, local government capital attraction competition, and the interaction term between the two and air pollution governance performance. The results show that the estimated coefficient between local government capital attraction competition and air pollution governance performance is significantly negative. This indicates that the local air pollution governance performance does not improve but shows some signs of decline along with the intensification of the competition for investment. Thus, Hypothesis 3a is supported. In addition, the interaction coefficient (Inter2) between local government competition and fiscal decentralization is significantly positive, indicating that fiscal decentralization suppresses the negative effect of government competition on air pollution governance performance, which is inconsistent with Hypothesis 3b.

In addition, the empirical results of the control variables are as follows. In both the baseline model I and the extended model II, the estimated coefficients of the one-period lagged variables of air pollution governance performance are significantly positive. This indicates that the current period's air pollution governance performance is indeed affected by the previous period's performance in the time dimension, which has a significant path-dependent feature and verifies the "snow ball" effect of the air pollution governance work. What is more, the level of air pollution governance performance shows a certain upward trend with the decrease in economic development degree and transportation intensity index, and the increase in population density index. In addition, the estimated coefficients of the level of science and technology and air pollution governance performance are negative but insignificant.

4.3. Robustness Test

(1) Control variable step-in treatment

Referring to Guo and Yang [48], the stepwise regression is performed by changing the order of different control variables into the model. The purpose is to verify the robustness of fiscal decentralization affecting air pollution governance performance. As can be seen from Table 5, the coefficient of fiscal decentralization shows a slight change with the addition of control variables one by one, while the direction of the coefficient of fiscal decentralization remains negative. All regression models are significant at the 1% and 5% levels, and this empirical result is not affected by the number of control variables and their order of inclusion, confirming the reliability of the core findings of this paper.

Table 5. Robustness checks: control variable step-in treatment.

	(1)	(2)	(3)	(4)	(5)	(6)
DEC	–0.381 **	–0.309 ***	–0.298 ***	–0.267 ***	–0.272 ***	–0.258 **
	(0.140)	(0.111)	(0.090)	(0.094)	(0.095)	(0.098)
L. pollution		0.562 ***	0.536 ***	0.523 ***	0.520 ***	0.506 ***
		(0.057)	(0.065)	(0.065)	(0.066)	(0.069)
Road			0.194 *	0.192 *	0.207 *	0.216 *
			(0.099)	(0.098)	(0.104)	(0.106)
GDP				–0.042	–0.050 *	–0.046 *
				(0.028)	(0.027)	(0.026)
Popuden					0.191	0.226 *
					(0.115)	(0.116)
Tech						–0.037
						(0.030)
Constant	0.005 ***	0.003 ***	0.002 ***	0.003 ***	0.002 **	0.002 **
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
N	240	240	240	240	240	240
R^2	0.705	0.800	0.809	0.810	0.811	0.812

Note: the standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Here, is the robustness test without the interaction term. See Appendix A Tables A1 and A2 for the complete test results.

(2) Replacement of key metrics and model treatment

To further confirm the robustness of the experimental results, the following methods are adopted to overcome the regression bias. First, replacing the measurement of fiscal decentralization metrics. Second, changing the estimation method of the model. Specifically, we use the ratio of local fiscal expenditure to national fiscal expenditure to measure the new fiscal decentralization metrics and adopt the OLS estimation method to regress the panel model. As can be seen from Table 6, columns (1) (3) (5) show the results of the metrics substitution test, and columns (2) (4) (6) show the results of the model replacement test. Whether replacing the measure of fiscal decentralization or using other estimation methods, the coefficient signs and significance levels of the core explanatory variables remain primarily consistent with Table 4, proving the accuracy and robustness of the core findings.

Table 6. Robustness checks: replacement of key metrics and model treatment.

Variables	FE	OLS	FE	OLS	FE	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
L. pollution	0.507 ***	0.506 ***	0.412 ***	0.413 ***	0.498 ***	0.497 ***
	(0.069)	(0.074)	(0.094)	(0.101)	(0.069)	(0.075)
DEC	–0.266 **	–0.258 **	–0.170 *	–0.166	–0.314 ***	–0.303 **
	(0.102)	(0.105)	(0.097)	(0.101)	(0.110)	(0.113)
Road	0.214 *	0.216 *	0.211 **	0.212 *	0.213 *	0.215 *
	(0.106)	(0.114)	(0.103)	(0.111)	(0.106)	(0.114)

Table 6. *Cont.*

Variables	FE	OLS	FE	OLS	FE	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
GDP	–0.044 *	–0.046	–0.053 **	–0.053 *	–0.045	–0.047
	(0.026)	(0.028)	(0.025)	(0.026)	(0.031)	(0.033)
Popuden	0.213 *	0.226 *	0.263 **	0.269 **	0.208 *	0.224 *
	(0.116)	(0.125)	(0.111)	(0.118)	(0.118)	(0.127)
Tech	–0.036	–0.037	–0.048	–0.049	–0.013	–0.015
	(0.030)	(0.032)	(0.028)	(0.030)	(0.038)	(0.041)
Invest			0.058 **	0.053 *		
			(0.025)	(0.026)		
Inter1			–17.071 ***	–15.935 ***		
			(4.683)	(4.796)		
FDI					–0.012 **	–0.012 *
					(0.006)	(0.006)
Inter2					2.500 **	2.416 **
					(0.923)	(0.960)
Constant	0.002 **	–0.002	0.002 **	–0.003	0.002 ***	–0.002
	(0.001)	(0.004)	(0.001)	(0.004)	(0.001)	(0.004)
N	240	240	240	240	240	240
R^2	0.813	0.962	0.831	0.966	0.816	0.963

Note: the standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.4. Heterogeneity of Region

China has a vast expanse of territory, and the resource conditions are different among regions. Thus, it is necessary to make further in-depth analyses at the regional level. We divide the whole sample into the south–north and coastal–inland regions, and the coefficients are estimated sequentially using the benchmark regression model.

(1) South–North regional differences

Taking into account the regional characteristics of heating in northern China and the distribution of heavy industries in China, this paper divides the sample into southern and northern regions according to the "Qinling-Huaihe" line. We attempt to examine whether the effect of fiscal decentralization on air pollution governance performance is significantly different in the north and south regions.

Columns (1) and (4) in Table 7 demonstrate the direct effect of fiscal decentralization on the governance performance of air pollution. This effect is corroborated in the northern region, where the higher the level of fiscal decentralization, the lower the governance performance of air pollution. In contrast, the coefficient of fiscal decentralization in the southern region is positive and insignificant, contrary to theoretical expectations. Columns (2) (5) and (3) (6) show the two paths that fiscal decentralization indirectly affects the governance performance of air pollution, respectively. The coefficient of pollution control investment is consistent with the expectation. Further analysis of the coefficient of the inter1 shows that fiscal decentralization in the northern region weakens the positive effect of pollution control investment on air pollution control performance. Moreover, this effect does not pass the significance test in the southern part. The coefficient of government competition is significantly negative in both northern and southern regions, confirming the existence of the "pollution paradise" effect. The coefficient of the inter2 shows that fiscal decentralization in the south weakens the negative impact of government competition on air pollution control performance. In contrast, this effect does not pass the significance test in the north.

It can be seen that the impact of fiscal decentralization on the governance performance of air pollution differs significantly between the southern and northern regions, consistent with Huang [49]. The possible reason is that the differentiation of industrial structure between the south and the north caused different behaviors of local governments in pollution governance. In the early days, most of the heavy industries in China were located in the north, and the industrial development process resulted in more air pollution emissions and

higher treatment costs. As a result, local governments tend to act negatively and the "race to the bottom" effect is prominent, which further magnifies the negative impact of the fiscal decentralization system on the governance performance of air pollution. In comparison, the southern region is more active in developing high-tech industries and the Internet economy. The government prefers to improve air quality to enhance the attractiveness of local factors and retain high-quality production factors, thus contributing to the improvement of air pollution governance performance.

Table 7. South–north differences in air pollution governance performance.

	Northern Regions			Southern Regions		
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
L. pollution	0.399 ***	0.336 **	0.333 **	0.592 ***	0.593 ***	0.533 ***
	(0.119)	(0.142)	(0.144)	(0.134)	(0.135)	(0.151)
DEC	–0.364 **	–0.256	–0.378 **	0.051	0.052	0.020
	(0.168)	(0.169)	(0.155)	(0.062)	(0.063)	(0.074)
Invest		0.077			0.002	
		(0.050)			(0.012)	
Inter1		–11.402 **			–0.157	
		(5.023)			(0.955)	
FDI			–0.026 **			–0.007 **
			(0.012)			(0.002)
Inter2			0.655			0.550 **
			(1.319)			(0.224)
Controls	YES	YES	YES	YES	YES	YES
N	120	120	120	120	120	120
R^2	0.640	0.661	0.657	0.983	0.983	0.984

Note: the standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$.

(2) Coastal and inland regional differences

This paper divides coastal and inland areas into two parts for comparison. Table 8 shows the empirical results. Most of the direct and indirect effects of fiscal decentralization on air pollution governance performance for inland areas pass the significance test. The results are similar to those in Table 4. In contrast, none of the above effects is significant in the coastal areas.

The possible reason for this is the difference in economic development between coastal and inland regions, which causes the various capacity of local environmental abatement funds supply. As a critical zone in implementing China's opening-up policy, the coastal regions have achieved earlier primitive accumulation by relying on the priority development policy and location advantage. In terms of financial independence, coastal governments are financially strong and less dependent on the central government than inland areas. They are more capable of solving air pollution problems, so the impact of fiscal decentralization on air pollution governance performance is not significant. At the same time, the inland areas are relatively lagging in terms of economic development level and gradually become the undertaking place for transferring high pollution industries in the government competition. The high cost of pollution control makes them greatly dependent on central transfer payments and supporting measures.

Table 8. Coastal–inland differences in air pollution governance performance.

	Coastal Regions			Inland Regions		
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
L. pollution	0.399 ***	0.336 **	0.333 **	0.428 ***	0.325 ***	0.421 ***
	(0.119)	(0.142)	(0.144)	(0.090)	(0.112)	(0.094)
DEC	–0.013	–0.037	–0.048	–0.532 ***	–0.375 **	–0.542 ***
	(0.049)	(0.039)	(0.073)	(0.114)	(0.151)	(0.117)

Table 8. *Cont.*

Variables	Coastal Regions (1)	(2)	(3)	Inland Regions (4)	(5)	(6)
Invest		–0.020			0.090 **	
		(0.018)			(0.042)	
inter1		1.848			–15.555 ***	
		(2.001)			(4.843)	
FDI			–0.015 *			–0.008
			(0.007)			(0.009)
inter2			0.852			0.834
			(0.471)			(0.821)
Controls	YES	YES	YES	YES	YES	YES
N	88	88	88	152	152	152
r2	0.945	0.946	0.946	0.765	0.794	0.766

Note: the standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

5. Discussion

The present study validated most of the hypotheses proposed and has several essential explanations and insights. Firstly, the fiscal decentralization system reduces the governance performance of air pollution. As the level of fiscal decentralization increases, local governments need to be more accountable for local fiscal revenues and expenditures and have a greater ability to allocate resources. Motivated by political promotion tournaments, the free-rider mentality of local officials in pollution governance tends to strengthen. They are more likely to adopt the strategic behavior of emission deregulation, which induces lower governance performance of air pollution. This negative effect is in line with the findings of scholars such as Yang et al. [50], Cai et al. [13], and Yin et al. [26]. Different from them, the present finding adopted composite rather than single indicators to measure the governance performance of air pollution. This finding remains after a series of robustness tests by adjusting the order of inclusion of control variables, replacing fiscal decentralization metrics and different model settings. Thus, our study is consistent with the first theoretical hypothesis and further reinforces the dominant position of the decentralized inhibition theory in the Chinese context.

The present study's results, as in the validated Hypotheses 2a and 2b, also show the positive effect of pollution control investment on the governance performance of air pollution is not sufficiently exploited in the context of fiscal decentralization. According to the pollution control experience of developed countries, environmental pollution problems can be effectively controlled only when pollution control investment occupies a relatively stable proportion of GDP. In both the overall and sub-regional samples, the governance performance of air pollution is sensitive to changes in pollution control investment, and the positive effect of pollution control investment on emission reduction is evident. However, this positive effect is largely weakened in the state of expenditure structure imbalance [51]. The study by Yu and Yang [52] also supports this view. Due to the different degrees of importance that each local government attaches to air pollution governance, the amount of pollution control investment, although rising year after year, is not as fast as the growth rate of the proportion of productive inputs. The fiscal expenditure structure continues to be biased. As a result, the positive effect of pollution control investment on air pollution governance performance is not sufficiently played.

Concurrently, hypothesis 3a was verified. Along with the intensification of local government competition for investment, the governance performance of air pollution in the jurisdiction does not improve but shows some signs of decline, confirming the Pollution haven hypothesis (PHH) [53,54]. Zhang et al. [55] have shown that under the fiscal decentralization system, jurisdictions may resort to environmental deregulation to compete for limited resources and markets driven by the incentive to maximize profits. However, inconsistent with the conclusions of previous studies, this paper found that the introduction of fiscal decentralization somewhat mitigates the negative effect of competition for capital on

the governance performance of air pollution. We attempt to explain this phenomenon. With the upgrading of the national governance concept and the adjustment of the corresponding assessment standards, local governments tend to introduce environment-friendly foreign enterprises under the trend of the central government's increasing emphasis on clean air. Then, green and advanced production technologies and pollution emission systems enter their jurisdictions, which reduces energy consumption and pollution emissions per unit of output, thus reducing the "race to the bottom" effect of local government capital attraction competition.

Meanwhile, the impact of fiscal decentralization on air pollution governance performance varies significantly across regions. The current results confirm that the negative impact of fiscal decentralization on air pollution governance performance is more prominent in the northern regions, which are more affected by the disadvantages of sloppy industries, and the inland regions with more backward economies. In these places, subject to regional resource endowment, industrial structure, and development level, local governments have limited capacity and incentive to governance air pollution, and rely more on central transfers, contributing to the negative effects of fiscal decentralization. This is consistent with the previous literature [34,49], confirming the regional heterogeneity of fiscal decentralization affecting air pollution governance performance. This finding may highlight the importance of regional cooperative governance [45] from a new perspective.

6. Conclusions and Implications

This paper analyzes the causal relationship and mechanism between the fiscal decentralization system and the governance performance of air pollution. Based on this, a series of theoretical research hypotheses are proposed. Meanwhile, the relationship is tested by a two-way fixed-effects model using provincial panel data for nine consecutive years from 2011 to 2019. Through empirical analysis, we find that the expansion of fiscal decentralization inhibits the improvement of air pollution governance performance. At the same time, the governance performance of air pollution has significant path dependence and strong time inertia. In terms of indirect effects, the increase in pollution control investment benefits improving air pollution governance performance. However, the introduction of fiscal decentralization has reduced the positive impact between the two. In addition, the competition among local governments to attract investment is not conducive to improving air pollution governance performance, and this negative effect is suppressed in the context of fiscal decentralization. By region, the extent to which the fiscal decentralization system affects air pollution governance performance varies across regions. Specifically, fiscal decentralization significantly negatively impacts air pollution governance performance in northern and inland regions, while the above effect is not significant in southern and coastal regions. This study can provide important theoretical and policy implications in the following areas based on the above empirical findings and conclusions.

6.1. Academic Implications

This study has two academic implications. First, this study uniquely introduces fiscal decentralization, which is an essential institutional factor, to explore its effect on air pollution governance performance, which can break through the limitations of the existing literature that mainly explores the influential aspects of air pollution governance performance under an economic framework. Thus, this study may expand the theoretical framework for analyzing the factors affecting air pollution. In addition, previous studies have typically focused on the overall impact of fiscal decentralization on air pollution, with less attention paid to the underlying mechanisms of action. This study verifies the internal paths of fiscal decentralization affecting the governance performance of air pollution from both horizontal and vertical dimensions. Therefore, the findings of this paper are essential for further understanding the relationship between fiscal decentralization and air pollution governance performance.

Second, this study uses the entropy method to construct a comprehensive index of air pollution governance performance, which can more comprehensively and objectively restore the overall situation of China's air pollution governance performance, so as to overcome the drawbacks of single pollutant indicators and expand existing air pollution-related research.

6.2. Policy Implications

According to the results of the analysis, the following policy implications are proposed to establish a long-term mechanism for air pollution prevention and governance and to create a win–win situation for the economy and environment.

(1) The fiscal decentralization system should be optimized, and a multi-performance assessment should be promoted. First of all, it should be clear that although the current stage of China's fiscal decentralization system harms the governance performance of air pollution, it cannot be a reason to deny the fiscal decentralization system itself. The reason is that this negative impact is characterized by phase, short-term and static. Based on the sustainability-oriented perspective, our consideration should focus on effectively dividing the fiscal power and corresponding responsibilities between the central government and local governments. Only in this way can we avoid the mismatch of authority and responsibility between local governments. Second, in recent years, the central government has been strengthening the weight of "environmental protection" metrics in the performance assessment system. This has encouraged local governments to develop a correct view of performance and has alleviated the vicious competition in local environmental supervision. Therefore, in the process of optimizing the performance appraisal system, the central government should further weaken the weight of GDP-oriented performance. Multiple binding indicators such as the quality of the air environment, the use of pollution control investment, and the use of special funds for air pollution governance should be included in the appraisal. Finally, since there is apparent time inertia in pollution governance, the "pollution for growth" concept should be firmly abandoned in the pollution governance process. To ensure the consistency of pollution governance behavior of officials and prevent them from making short-sighted behavior, it is suggested to establish a lifetime accountability system for officials.

(2) The structure of fiscal expenditure should be adjusted, and competition among local governments should be further regulated. According to the above empirical results, it is clear that pollution control investment has significant positive significance for improving air pollution governance performance. On the one hand, the central government should strengthen its coordination and coherence capacity under the current fiscal decentralization framework. It should also optimize the vertical transfer structure of environmental protection funds and fully exploit the guiding role of financial flows. On the other hand, local governments should adjust the structure of fiscal expenditures in favor of environmental protection to improve the efficiency of pollution control investment. In terms of government competition, the central government should increase its efforts to combat disorderly competition and firmly implement the central environmental inspection system. Then, they should strictly regulate local governments to attract investment and restrict the landing of high energy-consuming and high-polluting foreign investment projects. Strengthen the environmental monitoring of foreign-funded enterprises and guide local governments to form a competitive-cooperation relationship. Last but not least, to resolutely avoid short-term economic growth at the expense of the environment, local governments ought to encourage enterprises to actively learn advanced sewage technology and energy-saving and environmental protection concepts.

(3) The concept of collaborative governance in key regions should be strengthened, and an effective incentive mechanism should be developed. First of all, based on the perspective of city clusters, air pollution management needs to break through the shackles of the original administrative boundaries and highlight the collaborative governance concept. Nowadays, the community is particularly concerned about the air quality of

economically developed city clusters such as the Beijing–Tianjin–Hebei Region, the Yangtze River Delta, and the Guangdong–Hong Kong–Macao Greater Bay Area, and their air pollution management is also quite effective. In contrast, the inland areas of central and western China, as well as the old industrial areas in the north, are in an awkward situation outside the public's sight—either the inherent advantages are not enough, or the acquired development is limited. In these areas, air pollution governance faces multiple problems such as high pressure, heavy tasks, and low funding. Given this, we suggest that the joint prevention and control mechanism in key regions should be deepened. To ease the tense atmosphere caused by the financial imbalance among regional governments, a standardized and systematic ecological horizontal transfer payment system among local governments should be established. Secondly, air pollution control ought to fully account for geographical differences in economic, industrial, and population factors. Therefore, environmental protection policies and incentive mechanisms adapted to local conditions should be established. When the regional economy suffers losses due to the shutdown of air pollution treatment, compensation should be given for special financial transfers from the air fund. At the same time, the foreign investment projects undertaken within the jurisdiction should carefully assess their social and economic benefits from multiple perspectives, weighing the interests of various aspects before making a decision. In addition, when local governments are unable to bear the enormous amount of funds required for air pollution governance, the central government should provide corresponding support and guarantee the strength of vertical transfer payments to reach the equalization of basic public services for air governance.

6.3. Outlook

Based on the above point of view, it can be seen that fiscal decentralization acts on the governance performance of air pollution through vertical governance weaknesses and horizontal government competition. This paper provides complementary quantitative evidence on the environmental problems brought about by the interaction between different levels of government. However, due to the availability of data, this paper only analyzes the impact of fiscal decentralization on air pollution governance performance at the provincial level. The sample lacks refinement and depth, which provides space for further development in future studies.

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Appendix A

Table A1. Robustness test with an interaction term (Inter1).

	(1)	(2)	(3)	(4)	(5)	(6)
DEC	–0.247 **	–0.231 **	–0.222 **	–0.182 **	–0.188 **	–0.166 *
	(0.111)	(0.097)	(0.082)	(0.087)	(0.088)	(0.094)
Invest	0.083 **	0.048 *	0.047 **	0.052 **	0.052 **	0.053 **
	(0.034)	(0.025)	(0.023)	(0.024)	(0.023)	(0.024)

Table A1. *Cont.*

	(1)	(2)	(3)	(4)	(5)	(6)
Inter1	–24.158 ***	–14.911 ***	–14.545 ***	–15.406 ***	–15.521 ***	–15.935 ***
	(6.193)	(4.513)	(4.241)	(4.383)	(4.355)	(4.475)
L. pollution		0.479 ***	0.456 ***	0.440 ***	0.435 ***	0.413 ***
		(0.090)	(0.093)	(0.093)	(0.094)	(0.094)
Road			0.185 *	0.183 *	0.200 *	0.212 **
			(0.099)	(0.097)	(0.101)	(0.103)
GDP				–0.049 *	–0.059 **	–0.053 **
				(0.027)	(0.026)	(0.025)
Popuden					0.221 *	0.269 **
					(0.117)	(0.110)
Tech						–0.049 *
						(0.028)
Constant	0.005 ***	0.003 ***	0.003 ***	0.003 ***	0.002 **	0.002 **
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
N	270	240	240	240	240	240
R^2	0.748	0.816	0.824	0.826	0.826	0.829

Note: the standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A2. Robustness test with an interaction term (Inter2).

	(1)	(2)	(3)	(4)	(5)	(6)
DEC	–0.247 **	–0.231 **	–0.222 **	–0.182 **	–0.188 **	–0.166 *
	(0.111)	(0.097)	(0.082)	(0.087)	(0.088)	(0.094)
FDI	0.083 **	0.048 *	0.047 **	0.052 **	0.052 **	0.053 **
	(0.034)	(0.025)	(0.023)	(0.024)	(0.023)	(0.024)
Inter2	–24.158 ***	–14.911 ***	–14.545 ***	–15.406 ***	–15.521 ***	–15.935 ***
	(6.193)	(4.513)	(4.241)	(4.383)	(4.355)	(4.475)
L. pollution		0.479 ***	0.456 ***	0.440 ***	0.435 ***	0.413 ***
		(0.090)	(0.093)	(0.093)	(0.094)	(0.094)
Road			0.185 *	0.183 *	0.200 *	0.212 **
			(0.099)	(0.097)	(0.101)	(0.103)
GDP				–0.049 *	–0.059 **	–0.053 **
				(0.027)	(0.026)	(0.025)
Popuden					0.221 *	0.269 **
					(0.117)	(0.110)
Tech						–0.049 *
						(0.028)
Constant	0.005 ***	0.003 ***	0.003 ***	0.003 ***	0.002 **	0.002 **
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
N	270	240	240	240	240	240
R^2	0.748	0.816	0.824	0.826	0.826	0.829

Note: the standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

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