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How does government intervention affect regional air pollution? The role of intergovernmental tax competition and local environmental regulation

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The behavioral motivation and decision-making incentives of local governments are key aspects that affect the effectiveness of environmental management. This study takes Chinese local governments as the research object, selects the provincial dynamic panel data of Chinese Mainland from 2007 to 2020 for empirical estimation, and confirms that local government intervention plays an important role in the environmental pollution management of the jurisdiction: Under a single task orientation, tax competition will exacerbate air pollution, while environmental regulations will alleviate air pollution; Under the premise of parallel tasks and limited resources, these two local strategies have a restraining effect on each other and perform as a nonlinear relationship. The ultimate result is that the positive effects of environmental regulations cannot reverse the negative effects of tax competition. Furthermore, we introduced a spatial model and confirmed that there is an obvious spatial correlation between local government behavior. In the promotion tournament and "beggar thy neighbor" competition mode, local governments transfer the negative impact of tax competition to other regions, while keeping the positive impact of environmental regulations within their jurisdiction.

KEYWORDS

air pollution, environmental regulation, spatial correlation, tax competition, threshold effect

1 Introduction

The trade-off of benefit and cost between economic development and environmental protection has long been a vital topic of concern in academia, and it is also an essential consideration for local governments when formulating economic growth strategies. Local economic performance has always been an important basis for the assessment and promotion of local officials under China's centralized political system, leading to the gradual formation of a "promotion tournament" among local governments (Besley and Case, 1995; Li and Zhou, 2005; Zhou, 2007). Guided by economic growth, local officials have been incentivized to adopt various measures to enhance the economic output within their jurisdiction, in order to maximize work performance during their tenure and serve as a basis for seeking political promotion (Wheeler, 2001). And environmental quality is often a sacrifice of this competitive mode, leading to huge potential social costs and many ecological problems that are difficult to restore in the short term. Among many pollutants, due to the strong mobility and diffusion ability of polluted gases, their negative externalities are often difficult to measure. Local governments have the capacity and motivation to transfer this externality to other regions in order to minimize environmental management costs. This can be a good way for local governments to compete with each other and therefore has great research value. Sulfur dioxide emission and haze concentration has received the most public attention due to their harmfulness.

In the political context of China, economic activities and environmental management within the jurisdiction often are often subject to government intervention (Liu et al., 2012; Wu et al., 2013). When it comes to government competition, there are mainly two approaches, tax competition and expenditure competition: (1) relax tax collection or give tax exemption to reduce the expected cost of enterprises (Zodrow and Mieszkowski, 1986); and (2) expand fiscal expenditure scale to provide public infrastructure (Case et al., 1993). Among them, the main ways of tax competition are tax incentives, fiscal refunds, and the establishment of comprehensive supporting facilities for specific projects (Liu et al., 2023). Due to the fact that high polluting enterprises often bring greater output value, in the tax competition mode guided by economic growth, these enterprises will become the objects that Chinese local governments expect to absorb, thereby causing damage to environmental quality. When it comes to environmental management, the intervention measures of local governments mainly include environmental regulation laws and policies. As the government has absolute discourse power in China, the policies it issues will have a significant impact on environmental quality.

This study attempts to address these issues. How do the intervention strategies of local governments, including tax competition and environmental regulations, affect the air quality within their jurisdiction? In the case of limited resources, do these two parallel strategies interact with each other? If so, do they promote or inhibit each other? In addition, due to the externalities of air pollution and local government behavior, is there a spatial correlation between local government intervention strategies? If so, is it manifested as spatial transferring or spatial absorbing?

This study takes Chinese local governments as the research object, selects the provincial dynamic panel data of Chinese Mainland from 2007 to 2020 for empirical estimation, and confirms that local government intervention plays an important role in the environmental pollution management of the jurisdiction: The tax competition among local governments has intensified regional environmental pollution, while local government environmental regulations (especially environmental policies) have improved regional environmental quality. Under the premise of limited resources, these two local strategies have a restraining effect on each other. However, the ultimate result is that the positive effects of environmental regulations cannot reverse the negative effects of tax competition. This indicates that at present stage, competition among local governments in China still prioritizes economic growth, and although regional environmental quality is also an important aspect of concern for local officials, its weight is significantly lower than that of economic development. We used instrumental variable and GMM estimation approach to address endogeneity issues such as potential omitted variables and bidirectional causality. Furthermore, we introduced a spatial model and confirmed that there is an obvious spatial correlation between local government behavior. Tax incentives have exacerbated air pollution in other regions, but environmental regulatory policies have failed to improve air quality in surrounding areas. This indicates that the competition pattern among local governments in China is characterized by a “beggar thy neighbor” mode, where local governments tend to pass on negative impacts to other regions and retain positive impacts within their jurisdiction. This study analyzes the trade-off between economic growth and environmental protection in China, the largest developing country, over the past decade, and explores the effects of local government intervention and their competitive patterns. This may provide policy recommendations for central governments in China and developing countries to formulate fiscal, tax, and environmental policies.

2 Theoretical analysis

China’s environmental governance operates within a distinctive fiscal–administrative system in which the central government delegates extensive expenditure responsibilities to local governments while retaining substantial control over revenue authority (Zhou, 2007). This institutional configuration creates enduring fiscal pressure at the local level. Because local governments must shoulder the bulk of public service provision—including infrastructure, environmental protection, and social welfare—yet lack sufficient revenue autonomy, they are strongly motivated to pursue rapid economic expansion as a means of enlarging the local tax base. Under these constraints, tax competition becomes a primary policy tool: local governments engage in providing tax exemptions, land subsidies, and administrative conveniences to attract mobile capital (Keen and Marchand, 1997). Although such competitive strategies may promote short-term investment and GDP growth, they often come at the cost of weakened environmental management capacity. Local authorities may reduce inspection intensity, lower regulatory standards, or delay pollution control investments to avoid deterring firms, thereby exacerbating industrial emissions and environmental degradation (Konisky, 2007).

By contrast, enhanced environmental regulation serves as a powerful instrument for improving environmental quality. Command-and-control regulatory measures—such as mandatory emission standards, stringent monitoring, and penalties—have been shown to reduce pollution emissions, raise industrial energy efficiency, and stimulate technological innovation (He et al., 2020; Lin and Zhang, 2023). However, the implementation of environmental regulation in China is selective and strategically aligned with political incentives. Not all pollutants receive equal attention. For instance, sulfur dioxide (SO_2), historically designated by the central government as a "key controlled pollutant," is accompanied by explicit, quantifiable reduction targets and strong accountability mechanisms [①]. Therefore, local governments tend to prioritize SO_2 regulation, as failure to meet targets may directly jeopardize officials' evaluations. In contrast, haze (PM2.5) pollution, characterized by cross-regional spillovers, complex formation mechanisms, and high monitoring costs, receives relatively less enforcement attention. Empirical studies document this asymmetry, showing that local environmental efforts are skewed toward pollutants with strong central oversight and clear measurement criteria (Liang and Langbein, 2015).

Taken together, the combination of fiscal pressure, growth-oriented incentives, and selective enforcement produces an inherent tension between tax competition and environmental protection. While tax competition tends to worsen environmental conditions by incentivizing regulatory relaxation, environmental regulation—particularly for priority pollutants—improves air quality. The selective enforcement logic further explains why regulatory efforts are stronger for SO_2 than for haze. Therefore, under single-task orientation, tax competition exacerbates air pollution while environmental regulation alleviates it, and local governments exhibit greater emphasis on sulfur dioxide control than haze mitigation (H1).

When tax competition and environmental regulation operate concurrently, local governments face a multi-task environment in which competing policy goals require the allocation of limited administrative attention, fiscal resources, and regulatory capacity. Environmental regulation—especially command-and-control measures—entails substantial costs: it requires trained personnel, sophisticated monitoring systems, frequent inspections, and strict enforcement procedures (Alomari and Heffron, 2021; Søndergaard and Mosbech, 2022). When a local government chooses to emphasize environmental governance, it must allocate more fiscal and bureaucratic resources to these activities, thus increasing the intensity and credibility of regulatory enforcement.

Strengthened environmental regulation modifies the incentives of firms and local officials in ways that reduce the environmental harm associated with tax competition. Firms facing stringent environmental requirements bear higher compliance costs for pollution-intensive production. As a result, the attractiveness of jurisdictions relying on weak environmental enforcement as part of their tax competition strategy declines. Prior empirical research confirms that strong regulatory environments constrain firms' ability to exploit lax enforcement and deter them from adopting polluting technologies, even when economic incentives favor such choices (Auffhammer and Kellogg, 2011; Neves et al., 2020). At the same time, strengthened enforcement increases the risk and cost of regulatory evasion, narrowing the behavioral space for firms that might otherwise respond to tax incentives by increasing emissions.

In addition, stronger environmental regulation can influence local officials' strategic calculations. When central inspections, political events, or environmental accountability campaigns heighten the salience of environmental protection, local officials face increased pressure to demonstrate regulatory competence. During such periods, governments may temporarily shift administrative attention away from aggressive investment-attraction strategies, resulting in a partial correction of the environmental consequences of tax competition (Shi et al., 2020). Strengthened regulation can also increase the cost of pollution externalization for firms, making tax competition less effective in attracting high-emission industries.

Thus, in environments where environmental regulation is prioritized and sufficiently enforced, the expected negative environmental effect of tax competition becomes more constrained. Accordingly, the negative impact of tax competition on air quality will be weakened when environmental regulation is strengthened (H2).

Conversely, when local governments prioritize tax competition, the implementation and effectiveness of environmental regulation are significantly undermined. Tax competition limits environmental regulation through both fiscal and political channels. First, from a fiscal perspective, tax incentives and subsidies reduce government revenues, crowding out funds available for environmental monitoring, pollution control projects, and administrative capacity building (Nie et al., 2013; Liang and Langbein, 2015). Environmental regulation is resource-intensive: without adequate funding, inspection frequency declines, regulatory expertise weakens, and enforcement becomes inconsistent or symbolic.

Second, from a political incentives perspective, the structure of China's promotion tournament creates a strong bias toward economic performance. GDP growth remains one of the most observable, comparable, and politically rewarded indicators for local officials (Zhou, 2007). Although environmental goals are increasingly incorporated into cadre evaluation systems, their operational weight is often lower due to difficulties in measurement, attribution, and verification. As a result, when faced with trade-offs, officials often prioritize economic strategies—such as tax competition—that yield quick and measurable results. Environmental regulation, especially when costly or politically risky, becomes secondary.

Under these circumstances, the credibility of environmental regulation is weakened. Firms perceive the reduced likelihood of stringent enforcement and may respond by postponing environmental investments, exploiting regulatory loopholes, or shifting production toward more pollution-intensive processes (Blackman and Kildegaard, 2010). Local governments may intentionally relax standards or reduce inspection strictness to attract investment or avoid antagonizing key enterprises. This strategic relaxation undermines the intended pollution-reduction effects of environmental regulation.

Thus, tax competition not only directly contributes to pollution through the attraction of high-emission industries but also indirectly diminishes the capacity of environmental regulation to mitigate pollution. Based on these mechanisms, the positive impact of environmental regulation on air quality will be weakened when tax competition intensifies (H3).

Air pollution displays strong spatial spillover patterns due to atmospheric transport, allowing emissions generated in one locality to spread across neighboring jurisdictions. These physical characteristics of pollution mean that local governments' decisions regarding industrial development and regulatory enforcement have regional, not merely local, consequences.

When local governments engage in tax competition, they may attract pollution-intensive industries or encourage existing firms to expand production, thereby increasing emissions that diffuse across borders. Empirical evidence underscores that tax competition can significantly influence regional pollution levels beyond the initiating jurisdiction (Cremer and Gahvari, 2004).

Furthermore, tax competition itself is a spatially interdependent process. Regional governments observe and respond to each other's fiscal incentives and industrial policies, creating competitive dynamics such as "race to the bottom" in regulatory standards or fiscal incentives (Wilson, 1999; Rauscher, 2005). These interdependencies amplify the spatial spillovers of pollution: when one jurisdiction lowers taxes or relaxes standards to attract industry, neighboring jurisdictions may follow suit to avoid losing investment, reinforcing cross-regional environmental deterioration.

In contrast, environmental regulation in China remains largely localized. Command-and-control regulation is tied to local administrative responsibility systems and lacks robust cross-regional coordination mechanisms. Local officials are often held accountable for environmental performance within their own jurisdiction but face limited incentives to internalize regional environmental externalities. As a result, although pollution spills over, regulatory behaviors do not. The absence of strong mechanisms for cross-regional regulatory cooperation leads to weak spatial dependence in environmental regulation (Auffhammer and Kellogg, 2011).

This asymmetry—pollution and tax competition spilling over, but environmental regulation remaining locally contained—creates a structural imbalance in regional environmental governance. Therefore, tax competition produces spatial spillover effects on air pollution, while environmental regulation does not (H4).

Existing literature evaluated the implementation effectiveness of government environmental policies, analyzed the impact of tax competition on environmental quality, or explored the spatial spillover effects of air pollution and tax competition. However, as two parallel government intervention measures, local governments with the goal of maximizing performance often face a trade-off between tax competition strategies and environmental regulation strategies under the premise of limited resources. The implementation effects inevitably interact with each other, and selecting one for a single analysis cannot fully reflect the cost-benefit balance of local governments for economic growth and environmental management. This is especially true under the influence of China's centralized political system and local government competition mode. Therefore, it is more reasonable to include them in a unified research framework. In addition, simple linear relationships may not be well summarized, especially in China where local governments have absolute discourse power. When one policy is given priority, the implementation of another policy may be obstructed or even halted. Therefore, this study systematically analyzes the interaction, spatial correlation, and nonlinear relationship between government intervention policies, which may be more in line with China's actual situation. The conclusion of this study provides new evidence for research in the fields of environmental policy evaluation, tax competition, and environmental pollution, and also provides practical reference for the formulation of public policies in developing countries.

3 Methods

3.1 Baseline model

Some omitted variables may lead to a biased estimation and the two-way fixed effect (TWFE) model can overcome the endogeneities caused by unobservable factors. Therefore, the TWFE model with panel data is introduced as baseline regression model to explore the effects of tax competition and environmental regulation of local governments on regional air pollution. The specification is shown in Equation 1, where i and t indicate province and year, respectively. air_pol represents the air pollution variable, which will be measured using emissions of SO_2 in exhaust gas and annual average concentration of PM2.5. tax_comp and env_reg respectively represent intergovernmental tax competition and local environmental regulation. X is control variable vector. To reduce the error from omitted variables, μ_i and δ_t are introduced as province fixed effects and year fixed effects. ε_{it} is the i.i.d. disturbance term. The standard errors in the estimation results are clustered at the province level.

$$air\_pol_{it} = \beta_0 + \beta_1 tax\_comp_{it} + \beta_2 env\_reg_{it} + \Gamma' X_{it} + \alpha\mu_i + \gamma\delta_t + \varepsilon_{it} \quad (1)$$

3.2 Variables

The dependent variable is air pollution. Referring to Tan et al. (2022), this study uses emissions of sulfur dioxide (SO_2) and annual average concentration of haze pollution (PM2.5) for measurement. The haze pollution data are obtained from the satellite monitoring grid data of PM2.5 concentration released by the Center for Social and Economic Data and Application of Columbia University. SO_2 is measured by sulfur dioxide emissions in exhaust gas at province level. All the pollution variables are in natural logarithmic form.

The main explanatory variables are intergovernmental tax competition and local government environmental regulation. Although China carried out Tax Sharing System reform in 1994, the tax legislation power is still highly concentrated in the central government up to now, and local governments do not have rights to decide tax categories and tax rates in the real sense. Except for some regional tax policies implemented by the central government, all provinces execute exactly the same tax policies. As a result, the tax competition strategy among Chinese local governments is mainly reflected in the competition of effective tax rates at the present stage: Through various forms of preferential taxation policies such as tax breaks, subsidies, and refunds, the competitive strength is expanded in order to attract investment (Yacouba, 2022; Liu et al., 2023). These implicit competition strategies are difficult to reflect through tax rates, and tax revenue is closely related to regional production activity. Therefore, referring to the approach proposed by Tan et al. (2022), the intergovernmental tax competition level (TC) has following specification:

$$TC_{it} = \frac{\sum_i tax_{it}/GDP_{it}}{tax_{it}/GDP_{it}}$$

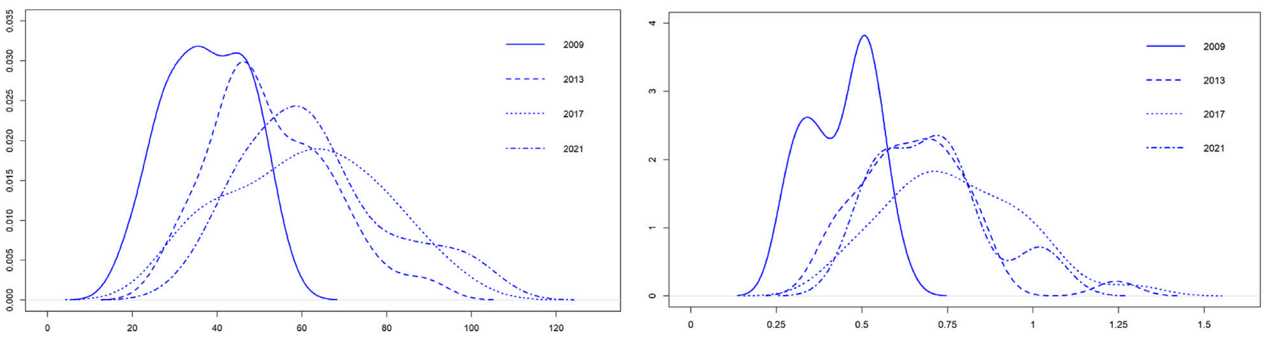

FIGURE 1
Kernel density curve of the frequency and its proportion of environmental related vocabulary.

where *tax* is the tax revenue of local government. It reflects the relative ability of local government to compete for tax resources, and a larger value indicates a higher level of tax competition.

Referring to Chen et al. (2018), we measure local governments' environmental regulatory efforts (*Reg*) using the proportion of environment-related vocabulary frequency in provincial government work reports ②. Traditional proxies—such as environmental protection investment, pollution control expenditure, or pollution tax rates—capture only single policy dimensions and cannot fully represent the broad set of regulatory tools applied by governments, including administrative orders, command-and-control measures, regulatory tightening, and incentive-based environmental governance. In contrast, text-based indicators reflect not only formal policies but also the government's policy priorities, regulatory attention, and administrative willingness, which constitute essential components of actual governance intensity.

Recent public administration and environmental economics literature provides increasing evidence that government documents and textual signals reliably capture policy preferences and implementation strength. Studies show that textual frequency and sentiment extracted from official reports strongly correlate with substantive policy actions, bureaucratic attention, and regulatory enforcement (Shi et al., 2019; Cao et al., 2025). In the Chinese context, government work reports function as authoritative policy agendas that guide local bureaucratic behavior, and their textual emphasis significantly influences subsequent policy implementation (Chen et al., 2018; Sun et al., 2023). Therefore, using the share of environmental vocabulary provides a multidimensional indicator that captures the intensity of regulatory orientation beyond what traditional quantitative inputs can offer. Moreover, text-based measures effectively mitigate endogeneity concerns arising from reverse causality between pollution and fiscal or regulatory inputs, as emphasized by Chen et al. (2018).

Figure 1 presents the kernel density distribution of environmental vocabulary frequency and its share in provincial reports. Despite slight fluctuations in recent years, both indicators exhibit an upward trend overall, suggesting a steady increase in the policy attention devoted to environmental issues by local governments. This trend further supports the validity of using textual emphasis as a proxy for regulatory strength.

To eliminate the possible interference of other factors on the identification of tax competition and environmental regulation effects, this study introduces control variables of province level based on previous research, including: (1) Government intervention (*Gov*). It is represented by the proportion of local government fiscal expenditure to regional GDP. (2) Fiscal decentralization (*FD*). It is represented by the ratio of fiscal revenue to fiscal expenditure. (3) Economic development (*PGDP*). It is represented by regional *per capita* real GDP. (4) Industrialization (*Ind*). It is represented by the proportion of regional industrial added value to regional GDP. (5) Trade liberalization (*Tra*). It is represented as the proportion of total amount of import and export trade to regional GDP. (6) Urbanization (*Urb*). It is represented as the proportion of urban permanent resident population to permanent resident population. (7) Population density (*Pop*). It is represented as the ratio of population to geographical area. (8) Traffic and transportation (*Trans*). It is represented as the ratio of highway mileage to geographical area.

This study uses the dynamic panel data of 30 provinces in Chinese mainland from 2007-2020. The Tibet Autonomous Region was excluded from the sample due to missing data. The original data involved are from *China Statistical Yearbook, China Statistical Yearbook of Environment, Finance Yearbook of China* and statistical yearbooks and official statistical reports of provinces. Table 1 reports the summary statistics of the variables.

4 Results

4.1 Benchmark regression results

The benchmark estimation results are reported in Table 2. We first conducted F-tests for the joint significance of individual and time effects to determine the appropriate panel specification. The results strongly reject the null hypotheses of no individual fixed effects and no time fixed effects ($p < 0.001$ in both cases), indicating that both cross-sectional and temporal heterogeneity should be controlled for. Next, we performed Hausman tests comparing the random effects (RE) and two-way fixed effects (TWFE) models. The estimated coefficients in column (1) and (5) are obtained from RE

TABLE 1 Summary statistics.

Meaning	Symbol	Obs	Mean	S.D.	Max	Min
Natural logarithm of SO_2 emission	$\ln SO_2$	420	3.469	1.235	5.208	−1.175
Natural logarithm of annual average concentration of PM2.5	ln PM2.5	420	5.689	0.967	7.190	3.270
Tax competition level (using tax revenue)	*TC*	420	1.072	0.282	1.759	0.458
Tax competition level (using fiscal revenue)	*TC_1*	420	1.015	0.233	1.697	0.488
Tax competition level (using FDI)	*TC_2*	420	2.195	1.559	8.642	0.027
Environmental regulation (using vocabulary frequency proportion)	*Reg*	420	0.631	0.210	1.390	0.183
Environmental regulation (using word number proportion)	*Reg_1*	420	0.882	0.286	1.920	0.271
Environmental regulation (using fiscal expenditure on environmental protection)	*Reg_2*	420	0.075	0.053	0.335	0.010
Government intervention	*Gov*	420	0.248	0.110	0.758	0.097
Fiscal decentralization	*FD*	420	0.501	0.194	0.951	0.148
Economic development	*PGDP*	420	46000	27269	164158	7778
Industrialization	*Ind*	420	0.353	0.085	0.574	0.100
Trade liberalization	*Tra*	420	0.296	0.332	1.670	0.008
Urbanization	*Urb*	420	0.563	0.135	0.938	0.282
Population density	*Pop*	420	464.673	685.528	3945.798	7.708
Traffic and transportation	*Trans*	420	290.665	264.330	1339.470	3.005

model regression, and coefficients in column (2) and (4) are obtained from TWFE model regression. The test statistics are χ^2 = 150.60 and χ^2 = 140.69, respectively, both significant at the 1% level, which rejects the RE specification in favor of the TWFE model. Therefore, the baseline regressions are estimated using a TWFE model.

Tax competition has a positive impact on sulfur dioxide emission and haze concentration, and is significant at the statistical level of 5%, indicating that tax competition among local governments worsens the air quality within the jurisdiction. From an economic perspective, a single unit increase in tax competition level induce to sulfur dioxide intensity increasing by 1.12% and haze pollution intensity by 0.14%. On the other hand, there is a negative and statistically significant relationship between environmental regulation and sulfur dioxide emission, but statistically insignificant relationship between environmental regulation and haze concentration, indicating that local government environmental regulation alleviated the sulfur dioxide pollution within their jurisdiction while effective management of haze pollution has not yet been formed. From an economic perspective, the inhibitory effect of environmental regulations on sulfur dioxide pollution is also obviously greater than that on haze pollution. In addition, along with the central and local tax and environmental policies deepened, regional pollution behavior may exhibit a ratchet effect, and firms in different jurisdictions will adjust their production plan and pollution discharge levels (Zhou et al., 2023). Therefore, it is necessary to take into account linear time trends, and the regression results are reported in column (3) and (7). Furthermore, an interaction term of time trend and province FE is introduced, and the results are reported in column (4) and (8). The estimated coefficients are all consistent with those in benchmark regression. H1 is verified.

4.2 Endogeneities

To address the potential endogeneity arising from the bidirectional causality between intergovernmental tax competition and air pollution, as well as possible omitted variables, this study follows existing literature and introduces an instrumental variable approach. Consistent with Tan et al. (2022), the number of prefecture-level cities within a province is first considered as an exogenous source of variation for tax competition. The administrative division of prefectures in China is determined exclusively by the central government and remains historically stable, reflecting political and administrative considerations rather than local economic, fiscal, or environmental conditions. This feature ensures that the instrument is not influenced by contemporaneous shocks to regional economic development or pollution levels, satisfying the exogeneity criteria required for a valid IV. Prior studies similarly emphasize that administrative boundaries in China are institutional constructs rather than outcomes of local policy choices, thereby supporting their use as exogenous determinants in empirical identification (Nathan and Qian, 2014; Jin et al., 2020). Moreover, within China's promotion tournament framework (Zhou, 2007), a larger number of prefectures within a province intensifies interjurisdictional competition by lowering each official's relative promotion probability, thereby strengthening incentives for tax-based competition. This mechanism provides a clear and theoretically grounded channel

TABLE 2 Basic regression results.

Dependent variable	ln SO_2	ln SO_2	ln SO_2	ln SO_2	ln PM2.5	ln PM2.5	ln PM2.5	ln PM2.5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TC	1.651*** (0.440)	1.122*** (0.187)	1.750*** (0.261)	1.143** (0.507)	0.343*** (0.091)	0.139** (0.070)	0.310*** (0.098)	1.400*** (0.249)
Reg	−0.356** (0.160)	−0.203** (0.099)	−0.292*** (0.123)	−0.425** (0.212)	0.036 (0.033)	−0.013 (0.026)	0.043 (0.033)	0.134 (0.121)
Gov	4.863*** (1.254)	1.069* (0.587)	6.375*** (0.717)	5.243** (2.117)	1.441*** (0.292)	0.445** (0.191)	1.612*** (0.299)	0.610 (0.548)
FD	5.739*** (0.731)	1.841*** (0.519)	5.586*** (0.603)	5.986*** (0.805)	1.425*** (0.228)	0.230 (0.256)	1.293*** (0.243)	2.782*** (1.062)
PGDP	−0.001*** (0.000)	−0.001*** (0.000)	−0.001*** (0.000)	−0.001*** (0.000)	−0.001*** (0.000)	−0.001* (0.000)	−0.001 (0.000)	0.001 (0.000)
Ind	4.498*** (1.196)	0.635 (0.574)	2.986*** (0.749)	4.680*** (1.725)	0.235 (0.366)	−0.309 (0.303)	0.037 (0.383)	2.487*** (0.882)
Tra	−0.541 (0.449)	−0.419** (0.196)	−0.394 (0.275)	−0.842* (0.448)	−0.194* (0.115)	−0.144 (0.093)	−0.136 (0.104)	−0.015 (0.644)
Urb	0.847 (1.916)	3.455*** (0.800)	2.202* (1.150)	−1.129 (1.597)	−0.945** (0.402)	−0.075 (0.357)	−0.466 (0.599)	−2.806** (1.418)
Pop	−0.001 (0.001)	−0.001*** (0.000)	−0.001 (0.001)	0.001*** (0.000)	−0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Trans	−0.001 (0.001)	−0.001** (0.000)	0.001 (0.001)	−0.002* (0.001)	−0.000 (0.000)	0.000*** (0.000)	−0.000 (0.000)	−0.001 (0.001)
_cons	−2.503** (1.218)	0.944 (0.975)	−3.719*** (1.326)	−1.413 (1.801)	5.056*** (0.304)	4.643*** (0.384)	3.481*** (0.576)	3.105*** (0.840)
R^2	0.833	0.927	0.839	0.814	0.739	0.849	0.743	0.917
Obs	420	420	420	420	420	420	420	420
Province FE	No	Yes	Yes	No	No	Yes	Yes	No
Year FE	No	Yes	No	No	No	Yes	No	No
Time trend	No	No	Yes	No	No	No	Yes	No
Time trend ×Province FE	No	No	No	Yes	No	No	No	Yes

(1) *** denotes significance at 1% level, ** at 5% and * at 10%. (2) The province-level cluster standard errors are reported in parentheses.

through which the IV affects tax competition but not air pollution directly, satisfying the relevance condition.

However, given that the number of prefectures does not vary over time, it cannot directly capture intertemporal changes in tax competition intensity in a panel setting. Following Nathan and Qian (2014), this study constructs an interaction instrument between the number of prefectures in a province and the national average level of tax competition in year *t*. National tax competition is determined by macro-level economic and political conditions and is not influenced by a single province's environmental quality, which reinforces the IV's exogeneity. Similar interacted or "shift-share" type IVs have been widely used to generate exogenous temporal variation while preserving the institutional exogeneity of the underlying source variable (Goldsmith-Pinkham et al., 2020; Adao et al., 2019). The two-stage least squares (2SLS) regression results are reported in Table 3. In the first stage regression, the IV are negatively correlated with tax competition. In the second stage regression, the estimated tax competition effect and environmental regulation effect are consistent with the benchmark results.

Although the endogeneity issue is partially alleviated by the TWFE model, there are still potential omitted variables that can interfere with the estimations. Considering that regional air pollution emissions may be path-dependent on previous air quality, the lagging term of air pollution variables are introduced for regression and GMM estimation approach are applied. GMM estimator can correct for the bias caused by the endogenous independent variables, and also facilitates the construction of more efficient estimates of dynamic panel data models with unobservable heterogeneity, heteroscedasticity and autocorrelation of individual observations (Arellano and Bover, 1995; Blundell and Bond, 1998). The system GMM (SYS-GMM) leverages the information from both cross-sectional and time-differential variations of variables, making it more efficient and exhibiting superior finite sample properties. The consistency of GMM estimator depends on two conditions: the error terms do

TABLE 3 Solution to endogeneity.

Dependent variable	*TC*	ln SO_2	*TC*	ln PM2.5	ln SO_2	ln PM2.5
	First stage	Second stage	First stage	Second stage	SYS-GMM	SYS-GMM
	(1)	(2)	(3)	(4)	(5)	(6)
TC		0.193*** (0.061)		0.046*** (0.015)	0.472*** (0.137)	0.201*** (0.063)
Reg	3.955 (2.397)	−1.155** (0.512)	3.955 (2.397)	−0.169 (0.126)	−0.370** (0.174)	−0.085** (0.035)
IV	−0.085*** (0.030)		−0.085*** (0.030)			
$L.SO_2$					0.705*** (0.038)	
L. PM2.5						0.914*** (0.028)
AR (1)					0.000	0.006
AR (2)					0.088	0.210
Hansen test					0.472	0.485
Obs	420	420	420	420	390	390
Controls	Yes	Yes	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

TABLE 4 Robustness checks–dependent variable: ln SO_2.

Robustness checks	Fiscal revenue	FDI	Word number proportion	Fiscal expenditure on environment protection	Winsorize (5%)	Exclude municipalities
	(1)	(2)	(3)	(4)	(5)	(6)
TC	2.595*** (0.287)	−0.021* (0.012)	2.604*** (0.287)	0.770*** (0.175)	1.151*** (0.175)	1.482*** (0.224)
Reg	−0.361*** (0.118)	−0.222* (0.129)	−0.385*** (0.119)	−1.639** (0.787)	−0.261*** (0.094)	−0.224** (0.105)
Obs	420	420	420	420	420	364
Controls	Yes	Yes	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

not exhibit second-order serial correlation and the IVs are valid. This study applied Arellano-Bond (AR) test for first- and second-order autocorrelation in the first-differenced errors, and the Hansen test for overidentifying restrictions. The GMM estimation results are reported in column (5) and (6) in Table 3. The prerequisites for GMM estimators are satisfied. The first-order lagged terms of dependent variables are significantly positive, which implies that the air pollution has a temporal extensibility, and a large intensity of previous air pollution exacerbated the current air quality. The SYS-GMM estimated coefficients of tax competition and environmental regulation are consistent with benchmark results.

4.3 Robustness checks

Robustness checks for the benchmark results are reported in Tables 4, 5.

1. Alternative measurements for tax competition. Considering that local governments may not only compete through tax policies, but also provide incentives through various types of revenue channels. Therefore, we replace the tax revenue with fiscal revenue and use a similar approach to construct the tax competition indicator:

TABLE 5 Robustness checks–dependent variable: ln PM2.5.

Robustness checks	Fiscal revenue	FDI	Word number proportion	Fiscal expenditure on environment protection	Winsorize (1%)	Exclude municipalities
	(1)	(2)	(3)	(4)	(5)	(6)
TC	0.566*** (0.074)	−0.006** (0.003)	0.567*** (0.074)	0.305*** (0.068)	0.135** (0.053)	0.278*** (0.068)
Reg	0.024 (0.031)	0.053 (0.032)	0.022 (0.031)	−0.380 (0.292)	−0.004 (0.029)	0.029 (0.032)
Obs	420	420	420	420	420	364
Controls	Yes	Yes	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

$$TC\_1_{it} = \frac{\sum_i revenue_{it}/GDP_{it}}{revenue_{it}/GDP_{it}}$$

A larger value indicates a higher level of tax competition. In addition, many previous studies introduced FDI as a measure of tax competition. As is well known, foreign investment in China enjoys supra national treatment, so we also apply the same approach to construct tax competition indicator, and a larger value indicated a lower level of tax competition:

$$TC\_2_{it} = \frac{\sum_i FDI_{it}/GDP_{it}}{FDI_{it}/GDP_{it}}$$

It is important to clarify why the direction of the FDI-based indicator differs from the tax-revenue-based indicator. When using tax revenue (or fiscal revenue) relative to GDP, lower revenue shares imply stronger tax competition, because local governments often reduce taxes or grant fiscal concessions to attract capital. By contrast, when FDI is used to construct the indicator, the underlying logic is reversed. A higher ratio of FDI to GDP reflects stronger tax competition, as foreign investment in China enjoys preferential tax treatment, and regions engaging more aggressively in tax concessions tend to attract more FDI inflows. Therefore, when constructing the indicator as the ratio between national and local FDI levels, a larger value corresponds to weaker local tax competition, which is consistent with the economic interpretation embedded in the FDI-based measure. This opposite direction stems from the different mechanisms through which tax revenue and FDI relate to local governments' competitive fiscal strategies.

2. Alternative measurements for environmental regulation. Referring to the approach of Chen et al. (2018), we use the proportion of environment-related words number to the total words number in the government working report as an alternative proxy for environmental regulation (Reg_1). In addition, local governments' investment in environmental protection projects also reflects the willingness and intensity of environmental regulation to a certain extent. Therefore, the proportion of local fiscal expenditure on environmental protection to regional GDP is introduced as another alternative indicator of environmental regulation (Reg_2).
3. Winsorize. In order to exclude the influence of outliers, the data on the left and right 1% of the observations' distributions are winsorized.
4. Exclude some samples. China's four municipalities (Beijing, Tianjin, Shanghai and Chongqing) directly under the central government have special administrative status and different administrative structures from other provinces, which may endow them with exceptional tax competition capacity and environmental regulation power, leading to a biased estimation, so these samples are excluded.

The results of robustness checks match our expectations, implying the credibility of the benchmark estimations. To further ensure the robustness of our core explanatory variables, we conduct a series of supplementary tests using alternative measures of tax competition and environmental regulation; the detailed procedures and results are reported in Supplementary Appendix A.

5 Further analysis

5.1 Spatial interaction

The above analysis shows that intergovernmental tax competition exacerbates the air quality while local environmental regulation alleviates the air pollution. However, due to the mobility of gases and the strategic interaction between local governments, there may be spatial spillover effects on air pollution, tax competition, and environmental regulation. The TWFE model cannot include this spatial correlation, which may result in biased estimations. This study applies spatial regression models to deal with this situation. Before conducting spatial regressions, a spatial correlation test should be carried out to ensure the applicability of spatial models.

5.1.1 Spatial correlation

The global Moran index (Moran's I) is introduced to test spatial correlations. The calculation formula is:

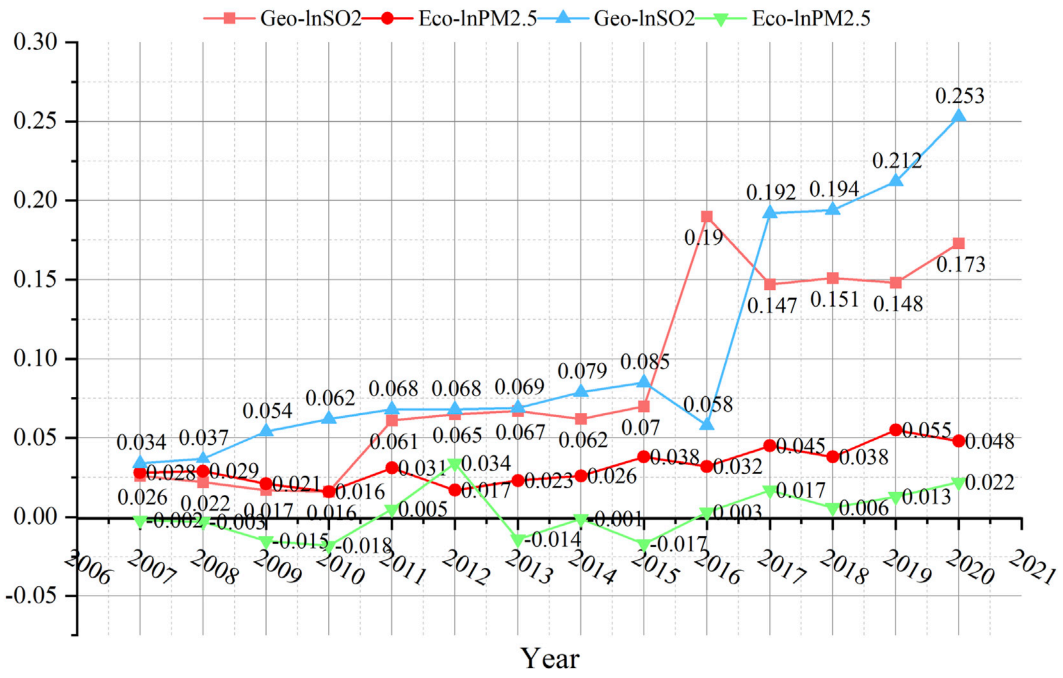

FIGURE 2
Global Moran's I in 2007–2020. Note: "Geo" denotes the index is weighted by geographical distance. 'Eco' denotes the index is weighted by economic distance.

$$Global\ Moran's\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(y_i - \bar{y}\right)\left(y_j - \bar{y}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}}$$

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2$$

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

where W_{ij} is the spatial weighted matrix. Due to the fact that local governments not only have geographical spatial connections, but also economic spatial connections, this study uses both geographical distance and economic distance as weights (local governments may interact with regions that are geographically adjacent or have similar economic situations). The specification of geographical distance weighted matrix is $W_{ij} = 1/d_{ij}^2, (i \neq j)$, where d_{ij} is the surface distance between provinces calculated based on latitude and longitude. The specification of economic distance weighted matrix is $W_{ij} = 1/|PGDP_i - PGDP_j|, (i \neq j)$, where $PGDP$ is the average provincial per capital GDP in the sample period (2007-2020). The values of the main diagonal elements ($i = j$) of these two kinds of matrix are 0. The matrices are normalized. Figure 2 shows the global Moran's I in each year. The geographical distance weighted sulfur dioxide pollution and haze pollution, as well as the economic distance weighted sulfur dioxide pollution, pass spatial correlation tests in most years, obtain positive Moran's I and show a clear upward trend, indicating that regional sulfur dioxide emissions have geographical and economic positive spatial correlations, while regional haze concentration only has geographical positive spatial correlations, and these spatial correlations are still strengthening over time. It preliminarily implies that regional air pollution has spillover effects, and the pollution emissions in this region will worsen air qualities in other regions. Taking 2020 as an example, the local Moran scatter plot further illustrates their local agglomeration situation, as shown in Figure 3.

5.1.2 Spatial regression

The results of spatial correlation test ensure the applicability of spatial models. The specifications of three kinds of spatial regression models, spatial autoregressive model (SAR), spatial error model (SEM) and spatial Durbin model (SDM) are shown in Equations 2–5. Specific tests need to be carried out respectively for the judgement of final form.

$$air\_pol_{it} = \rho\sum_{j=1}^{n} W_{ij} air\_pol_{it} + \beta_1 TC_{it} + \beta_2 Reg_{it} + \Gamma' X_{it} + u_i + \theta_t + \varepsilon_{it} \tag{2}$$

$$air\_pol_{it} = \beta_1 TC_{it} + \beta_2 Reg_{it} + \Gamma' X_{it} + u_i + \theta_t + \varepsilon_{it} \tag{3}$$

$$\varepsilon_{it} = \lambda\sum_{j=1}^{n} W_{ij}\varepsilon_{it} + \sigma_{it} \tag{4}$$

$$air\_pol_{it} = \rho\sum_{j=1}^{n} W_{ij} air\_pol_{it} + \beta_1 TC_{it} + \beta_2 Reg_{it} + \Gamma' X_{it} + W\_\beta_1\sum_{j=1}^{n} W_{ij} TC_{it} + W\_\beta_2\sum_{j=1}^{n} W_{ij} Reg_{it} + W\_\Gamma'\sum_{j=1}^{n} W_{ij} X_{it} + u_i + \theta_t + \varepsilon_{it} \tag{5}$$

ρ is the spatial autoregressive parameter. λ is the spatial error parameter. They reflect the effects of spatial lagged value of the

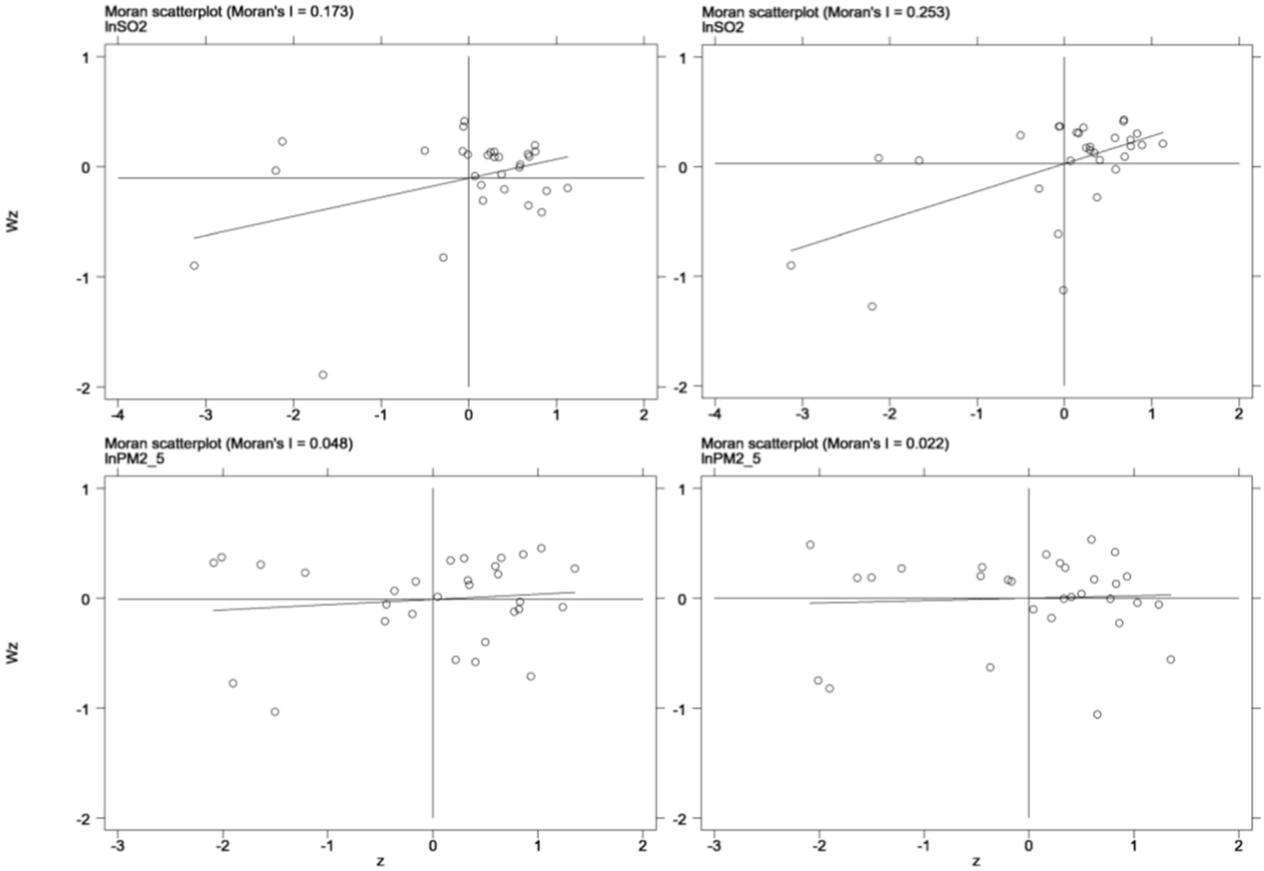

FIGURE 3
Local Moran's I scatter plot in 2020. Note: The scatter plot on the left is weighted by geographical distance. The scatter plot on the right is weighted by economic distance.

independent variable on itself. A positive/negative value of ρ or λ indicates that the air pollution of surrounding areas has a positive/negative spillover effect on that of this region. W_β is the spatial lagged coefficient of tax competition and environmental regulation, indicating the spatial effects of tax competition and environmental regulation strategies. W_Γ' is the spatial lagged coefficient of control variables. u_i, θ_t and ε_{it} are space effects, time effects and disturbance, respectively.

The spatial regression results weighted by geographical distance and economic distance are reported in Tables 7, 8. We ran regressions using SAR, SEM and SDM models with fixed effects. In addition, to ensure the robustness of the model selection procedure, we conducted Lagrange Multiplier (LM) tests for both spatial lag dependence and spatial error dependence. The results consistently indicate the presence of significant spatial lag and spatial error components, confirming that the data exhibit dual forms of spatial dependence. Together with the Wald tests and LR tests—both of which reject the null hypotheses that the Spatial Durbin Model (SDM) can be simplified to either the SAR or SEM specifications—these diagnostic results jointly support the use of the full SDM specification. The test results are reported in Table 6. Therefore, the SDM with fixed effects is adopted as the appropriate econometric framework for the empirical analysis, and the regression results are reported in column 3 and 6 in Tables 7, 8.

The coefficients of tax competition and environmental regulation are consistent with the benchmark results in both the geographical and economic spatial regressions, indicating that H1 continues to hold after accounting for spatial interactions. The spatially lagged term of tax competition is significantly associated with SO_2 emissions but not with PM2.5 concentrations, and its sign differs across spatial weight matrices—positive under geographical distance and negative under economic distance. By contrast, the spatial lag of environmental regulation remains insignificant in all specifications. These findings suggest that: (1) tax competition generates significant spatial spillovers, whereas environmental regulation does not, consistent with local governments' tendency to adopt "beggar-thy-neighbor" strategies that externalize pollution while internalizing economic benefits; (2) spatial spillovers are more pronounced for sulfur dioxide, a pollutant closely tied to heavy industry, which local governments often attract via preferential policies, and which also diffuses more readily across administrative boundaries; and (3) tax competition worsens air pollution in geographically adjacent regions (a pollution-transfer effect), while among provinces with similar economic development levels, competitive firm attraction may reduce pollution in peer regions (an absorbing effect), as noted in Tan et al. (2022). These empirical patterns provide strong support for H4. In addition, to

TABLE 6 Spatial diagnostic tests.

Dependent variable	ln SO_2		ln PM2.5	
Spatial weight matrix	Geographical distance	Economic distance	Geographical distance	Economic distance
LM test spatial lag	258.05***	69.93***	320.06***	36.25***
LM test spatial error	166.00***	57.62***	299.34***	66.14***
Wald test spatial lag	18.02**	79.88***	21.03**	20.10**
Wald test spatial error	20.50**	115.43***	29.59***	21.13**
LR test spatial lag	19.47**	109.92***	27.71***	20.50**
LR test spatial error	22.47**	105.52***	24.15***	20.03**

*** denotes significance at 1% level, ** at 5% and * at 10%.

TABLE 7 Spatial regression results–geographical distance weighted.

Dependent variable	ln SO_2	ln SO_2	ln SO_2	ln PM2.5	ln PM2.5	ln PM2.5
	SAR	SEM	SDM	SAR	SEM	SDM
	(1)	(2)	(3)	(4)	(5)	(6)
ρ	0.215*** (0.067)		0.201** (0.081)	0.516*** (0.064)		0.508*** (0.067)
λ		0.291*** (0.078)			0.530*** (0.066)	
TC	1.017*** (0.174)	1.032*** (0.173)	1.073*** (0.177)	0.115** (0.048)	0.129*** (0.048)	0.137*** (0.049)
Reg	−0.218** (0.091)	−0.183** (0.089)	−0.269*** (0.093)	−0.002 (0.025)	0.014 (0.024)	−0.021 (0.026)
W_TC			0.832* (0.501)			0.150 (0.136)
W_Reg			−0.417 (0.273)			−0.267*** (0.075)
R^2	0.720	0.694	0.800	0.654	0.617	0.617
Log-L	36.582	38.080	47.815	567.855	566.075	579.930
Obs	420	420	420	420	420	420
Controls	Yes	Yes	Yes	Yes	Yes	Yes
*W_* Controls	No	No	Yes	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

account for potential policy coordination among geographically connected provinces, we further supplement the baseline spatial weight matrices with a contiguity matrix, the results of which are reported in Supplementary Appendix B.

The decomposition of spatial effects further refines this interpretation, and for illustration, we discuss the case where sulfur dioxide serves as the dependent variable, with the corresponding results reported in Tables 9, 10. Under the geographical weight matrix, tax competition exhibits significantly positive direct and indirect effects on SO_2 emissions, indicating that competitive strategies not only intensify local pollution but also transmit environmental burdens to surrounding provinces through spatial diffusion. Under the economic distance matrix, the direct effect of tax competition remains positive while the indirect effect turns negative, implying that provinces at similar development stages engage in competition for mobile capital, creating an absorbing effect that modestly reduces pollution in economically comparable regions. By contrast, environmental regulation demonstrates a consistently negative and significant direct effect but no meaningful indirect effect, confirming that regulatory enforcement primarily operates within administrative jurisdictions rather than generating broader spatial spillovers. Together, these results show that tax competition amplifies environmental pressure both locally and regionally, whereas environmental regulation mainly produces localized improvements, highlighting the asymmetric spatial consequences of local government interventions and providing robust empirical support for H4.

A practical illustration of this pollution-shifting mechanism can be observed in the Beijing–Tianjin–Hebei region. As Beijing and

TABLE 8 Spatial regression results—economic distance weighted.

Dependent variable	ln SO_2	ln SO_2	ln SO_2	ln PM2.5	ln PM2.5	ln PM2.5
	(1)	(2)	(3)	(4)	(5)	(6)
	SAR	SEM	SDM	SAR	SEM	SDM
ρ	0.239*** (0.093)		0.110 (0.096)	−0.139 (0.090)		−0.135 (0.093)
λ		0.125 (0.109)			−0.129 (0.094)	
TC	1.109*** (0.172)	1.143*** (0.175)	0.923*** (0.161)	0.143*** (0.052)	0.135*** (0.052)	0.180*** (0.054)
Reg	−0.203** (0.092)	−0.194** (0.092)	−0.244*** (0.084)	−0.014 (0.027)	−0.014 (0.028)	−0.016 (0.029)
W_TC			−1.196** (0.518)			0.053 (0.168)
W_Reg			−0.378 (0.246)			−0.045 (0.083)
R^2	0.702	0.682	0.621	0.601	0.613	0.651
Log-L	34.543	32.342	87.303	542.915	542.679	552.932
Obs	420	420	420	420	420	420
Controls	Yes	Yes	Yes	Yes	Yes	Yes
$W\_$ Controls	No	No	Yes	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

TABLE 9 Direct effect, indirect effect and total effect - geographical distance weighted.

Effect	Variables	Coefficient	Z value	P value
Direct effect	W_TC	1.115***	6.11	0.000
Indirect effect	W_TC	1.246**	2.21	0.027
Total effect	W_TC	2.361***	3.87	0.000
Direct effect	W_Reg	−0.289***	−3.12	0.002
Indirect effect	W_Reg	−0.549	−1.57	0.117
Total effect	W_Reg	−0.838**	−2.15	0.032

*** denotes significance at 1% level, ** at 5% and * at 10%.

TABLE 10 Direct effect, indirect effect and total effect—economic distance weighted.

Effect	Variables	Coefficient	Z value	P value
Direct effect	W_TC	0.911***	5.44	0.000
Indirect effect	W_TC	−1.223**	−2.14	0.033
Total effect	W_TC	−0.312	−0.50	0.617
Direct effect	W_Reg	−0.255***	−3.07	0.002
Indirect effect	W_Reg	−0.435	−1.49	0.135
Total effect	W_Reg	−0.690**	−2.14	0.032

*** denotes significance at 1% level, ** at 5% and * at 10%.

Tianjin tightened environmental regulation and accelerated industrial upgrading, a substantial share of high-emission industries—such as steel, cement, and petrochemicals—relocated to neighboring Hebei. Prior studies show that while this industrial redistribution improved air quality in Beijing, it simultaneously increased SO_2 and PM2.5 emissions in adjacent Hebei cities, creating a clear cross-regional pollution transfer pattern consistent with the spatial spillover dynamics identified in our analysis.

5.2 Mechanisms

5.2.1 Moderating effect

In this subsection, we explore the underlying interactive relationship between tax competition and environmental regulation. Specifically, we introduce an interaction term $TC \times Reg$ into the benchmark regression model, the estimated results are reported in column (1) and (2) in Table 11. Furthermore, we have decentralized the interaction term, and the results are reported in column (3) and (4). The coefficients of tax competition are statistically significant and positive, and the interaction terms are significantly negative, indicating that the intensifying effect of tax competition on air pollution will weaken with the strengthening of government environmental regulations. It can be seen that local governments are not powerless in environmental management within their jurisdiction. When the central government issues environmental protection policies and

TABLE 11 Moderating effect.

Dependent variable	$\ln SO_2$	ln PM2.5	$\ln SO_2$	ln PM2.5
	(1)	(2)	(3)	(4)
TC	1.260*** (0.240)	0.227*** (0.075)	0.945*** (0.162)	0.132** (0.055)
Reg	0.356 (0.332)	0.152 (0.099)	−0.180* (0.100)	−0.009 (0.030)
$TC \times Reg$	−0.500* (0.288)	−0.150 (0.086)		
$(TC - \overline{TC}) \times (Reg - \overline{Reg})$			−0.500* (0.288)	−0.150* (0.086)
Obs	420	420	420	420
Controls	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

TABLE 12 Mechanisms.

Dependent variable	Env_exp	$\ln SO_2$	Env_cost	$\ln SO_2$
	(1)	(2)	(3)	(4)
TC	−0.023** (0.010)	1.049*** (0.184)	−21.666 (26.670)	1.085*** (0.187)
Reg	0.006 (0.006)	−0.284*** (0.099)	17.986** (8.682)	−0.195** (0.099)
Env_exp		−4.260*** (0.962)		
Env_cost				−0.001* (0.001)
Obs	420	420	420	420
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

local governments make them task oriented, the negative impact of tax competition can be effectively suppressed. Considering the interactive relationship between tax competition and environmental protection, we will further consider the nonlinear relationship between variables to explore the heterogeneous impact of tax competition and environmental protection on air pollution.

5.2.2 Mediating effect

To further uncover the internal transmission mechanisms through which tax competition and environmental regulation interact, we estimate a set of mediating effect models using sulfur dioxide emissions as the outcome variable. The results in Table 12 show clear evidence of the two hypothesized channels. First, tax competition significantly reduces the share of local environmental fiscal expenditure (Env_exp), and lower environmental spending is in turn associated with higher SO_2 emissions, indicating a resource-crowding mechanism through which intensified tax competition weakens the effectiveness of environmental regulation. This suggests that competition for investment reduces the fiscal space available for environmental governance, thereby diminishing regulatory enforcement capacity and ultimately worsening air quality. Second, environmental regulation is found to increase firms' compliance costs (Env_cost), measured by the ratio of environmental tax revenue to total local tax revenue; higher compliance costs subsequently reduce the effectiveness of tax competition in attracting firms, consistent with the view that stricter regulation attenuates the pollution-enhancing impact of tax-driven growth strategies. Together, these mediating pathways provide direct empirical support for the theoretical proposition that the mutual inhibition between tax competition and environmental regulation operates through both fiscal resource constraints and firms' cost structures, thereby deepening the explanation of how government behavior shapes environmental outcomes.

5.3 Nonlinear relationship

In this subsection, we introduce threshold regression model with panel data to explore the possible nonlinear relationship between tax competition, environmental regulation and air pollution.

TABLE 13 Threshold regression results.

Dependent variable	ln SO_2	ln PM2.5	ln SO_2	ln PM2.5
	(1)	(2)	(3)	(4)
$TC \cdot \boldsymbol{I}(Reg \le \gamma)$	1.839*** (0.512)	0.974*** (0.146)		
$TC \cdot \boldsymbol{I}(Reg > \gamma)$	1.694*** (1.658)	0.403*** (0.072)		
$Reg \cdot \boldsymbol{I}(TC \le \delta)$			−1.562*** (0.362)	0.105*** (0.026)
$Reg \cdot \boldsymbol{I}(TC > \delta)$			−0.116 (0.132)	0.003 (0.021)
Obs	420	420	420	420
Controls	Yes	Yes	Yes	Yes
Wald test	118.10***	117.90***	174.74***	106.89
Threshold	0.602	0.296	0.493	0.976
LR statistics-single	47.414**	3.007***	54.462**	3.236*
LR statistics-double	47.16	3.140	51.390	3.147
Bootstrap times	300	300	300	300

*** denotes significance at 1% level, ** at 5% and * at 10%. I(·) is indicator function, if the conditions in parentheses are satisfied, the value is 1; otherwise, it is 0.

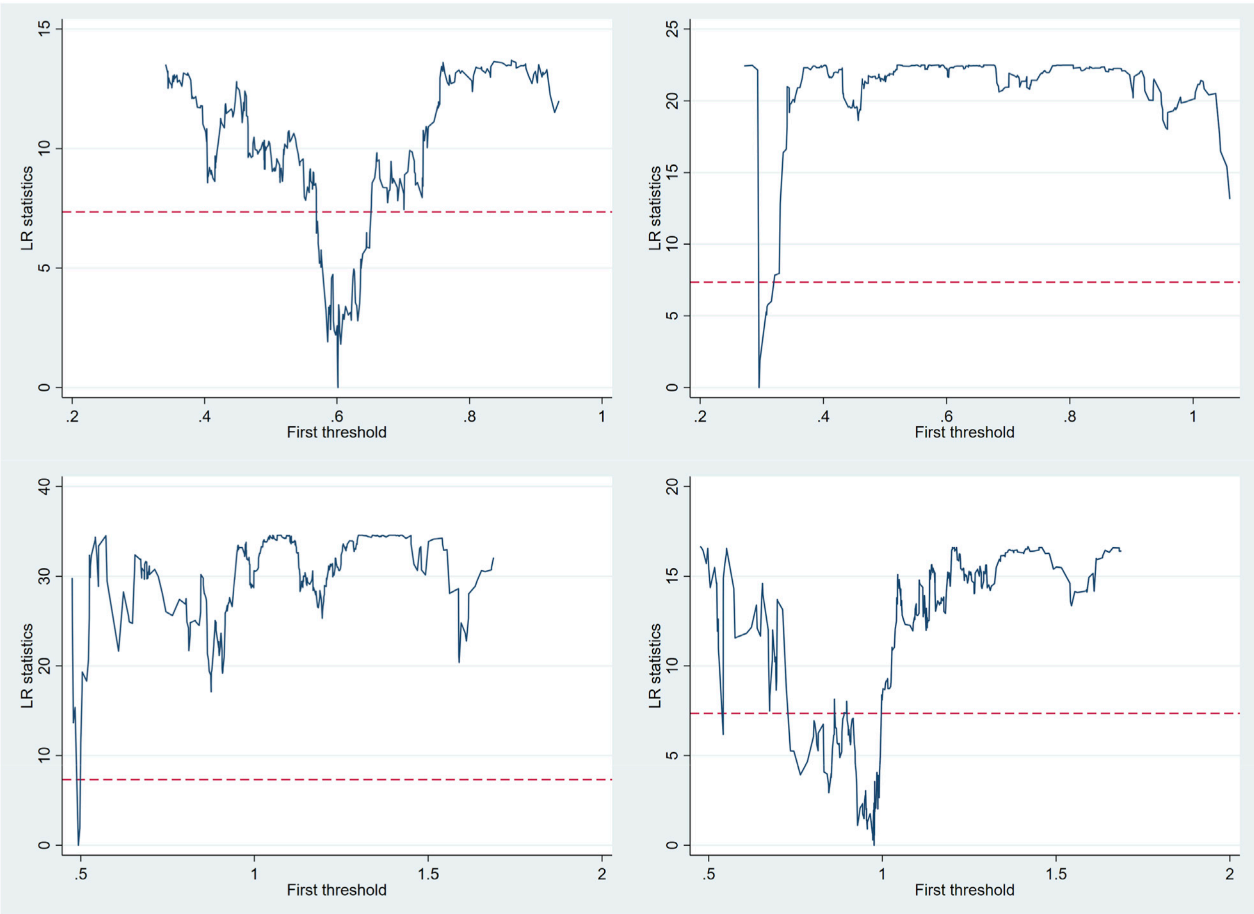

FIGURE 4
LR test results. Note: (1) The confidence level is 95%. (2) The figures correspond to regression (1)–(4) in Table 13.

Specifically, we will discuss the nonlinear effect of tax competition/environmental regulation on air pollution at different intensity of environmental regulation/tax competition.

5.3.1 Threshold effect

Before conducting the regression, we carry out a significance test for the threshold effect and estimate the threshold value (Hasen, 2000). The testing results are reported in Table 13. LR statistics of single threshold are 47.414, 3.007, 54.462 and 3.236, respectively, and they all passed the test at 5% confidence level. However, the double threshold did not pass the test. Therefore, we choose single threshold regression model for nonlinear analysis. The estimated threshold values are 0.062, 0.296, 0.493 and 0.976, respectively. The LR test results are also shown in Figure 4.

5.3.2 Threshold regression

The single threshold regression models with panel data are shown in Equations 6, 7:

$$air\_pol_{it} = \alpha_0 + \alpha_1 TC_{it} \cdot I\left(Reg_{it} \le \gamma\right) + \alpha_2 TC_{it} \cdot I\left(Reg_{it} > \gamma\right) + \Gamma' X_{it} + \mu_i + \theta_t + \varepsilon_{it} \tag{6}$$

$$air\_pol_{it} = \beta_0 + \beta_1 Reg_{it} \cdot I\left(TC_{it} \le \delta\right) + \beta_2 Reg_{it} \cdot I\left(TC_{it} > \delta\right) + \Gamma' X_{it} + \mu_i + \theta_t + \varepsilon_{it} \tag{7}$$

$I(\cdot)$ is indicator function, if the conditions in parentheses are satisfied, the value is 1; otherwise, it is 0. We select tax competition and environmental regulation as threshold variable respectively. γ and δ are their threshold values. The regression results are reported in Table 13.

It can be seen that: (1) From column (1) and (2), on both sides of the threshold, tax competition is positively associated with air pollutants, but the magnitude of this effect gradually decreases. Although the reduction in the impact on sulfur dioxide is not statistically significant, the effect on PM2.5 declines by 59%. This pattern suggests that environmental regulation can weaken—but not overturn—the destructive environmental impact generated by tax competition, thereby supporting H2.

This result reflects the underlying behavioral incentives and resource allocation logic of local governments. Under China's fiscal decentralization and promotion tournament system, local governments face intense competition for economic performance, leading them to prioritize tax incentives and investment-attraction strategies. When environmental regulation strengthens and crosses the estimated threshold, local officials must divert administrative attention and fiscal resources toward compliance monitoring and enforcement, which partially curbs the pollution-inducing consequences of tax competition. However, because tax competition directly supports measurable economic indicators that are crucial for promotion, while environmental gains remain less visible and harder to attribute, local governments continue to display a pro-growth bias even under relatively strong regulation. This explains why the negative effects of tax competition remain dominant and cannot be reversed. In addition, environmental regulation more effectively constrains pollution associated with haze rather than sulfur dioxide. As discussed earlier, sulfur dioxide emissions are largely generated by heavy industrial firms actively attracted through tax competition. Given their strong fiscal contribution and the wide diffusion range of SO_2, local governments often strategically relax regulation and externalize pollution to minimize political and administrative costs, diminishing the moderating role of environmental regulation in this domain.

(2) From column (3) and (4), when the intensity of tax competition is below the threshold value, environmental regulation significantly reduces air pollution, thereby improving environmental quality. Nevertheless, once tax competition exceeds the threshold, the effect of environmental regulation becomes statistically insignificant, and local environmental governance measures no longer influence pollution outcomes. This finding indicates that the governance capacity and regulatory determination of local governments become constrained under conditions of high tax competition, where the pursuit of economic indicators absorbs fiscal resources, administrative effort, and political attention that would otherwise support environmental enforcement.

This pattern also illustrates the hierarchical prioritization embedded in China's official promotion system. When tax competition is moderate, local governments can still allocate sufficient regulatory resources to enforce environmental policies. However, once competition intensifies beyond the threshold, the marginal political benefits of prioritizing GDP growth far outweigh those of preserving environmental quality. As a result, environmental regulation becomes secondary, and its effectiveness diminishes sharply, confirming that the destructive impact of tax competition on air quality outweighs the positive effects of environmental regulation. This institutional logic reflects the fact that economic growth remains the primary performance criterion in the promotion tournament, thereby verifying H3.

5.4 Heterogeneities

5.4.1 Regional heterogeneities

To further examine potential spatial heterogeneity, we conduct subgroup regressions for the eastern, central, and western regions of China, and the results are reported in Table 14. The results reveal clear regional differentiation in the mechanisms through which local government intervention affects air quality. When sulfur dioxide is used as the dependent variable, tax competition significantly increases emissions across all three regions, suggesting that the growth-oriented incentives embedded in China's fiscal decentralization and promotion system consistently induce local governments to adopt aggressive competition strategies regardless of regional development stage. In contrast, the mitigating effect of environmental regulation is observed only in the eastern region—where institutional capacity, regulatory sophistication, and administrative enforcement tend to be stronger—while it remains statistically insignificant in the central and western regions. When haze is examined, tax competition again exacerbates pollution in all regions, but environmental regulation exhibits no measurable improvement effect anywhere, underscoring the greater difficulty of governing diffuse, transboundary pollutants and the limited regulatory leverage available to local governments under resource constraints. Taken together, these results confirm that both the effectiveness of environmental regulation and the

TABLE 14 Regional heterogeneities.

Dependent variable	ln SO_2			ln PM2.5		
	Eastern	Central	Western	Eastern	Central	Western
	(1)	(2)	(3)	(4)	(5)	(6)
TC	1.384** (0.592)	1.792*** (0.335)	1.086*** (0.234)	0.321*** (0.112)	0.436*** (0.130)	1.082** (0.422)
Reg	−0.788*** (0.205)	−0.018 (0.166)	−0.119 (0.119)	0.013 (0.055)	−0.066 (0.058)	0.124 (0.275)
Obs	182	84	154	182	84	154
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

TABLE 15 Policy interference.

Dependent variable	ln SO_2	ln SO_2	ln PM2.5	ln PM2.5
	(1)	(2)	(3)	(4)
TC	1.161*** (0.321)	0.384* (0.205)	0.212* (0.128)	0.188* (0.102)
Reg	−0.411** (0.164)	−0.137* (0.072)	0.008 (0.045)	0.024 (0.048)
Obs	240	180	240	180
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

*** denotes significance at 1% level, ** at 5% and * at 10%.

manifestation of tax competition vary meaningfully across regions, reflecting differences in economic structure, fiscal capacity, and regulatory enforcement.

5.4.2 Policy interference

To address temporal heterogeneity and potential policy interference, this study further divides the sample into two periods based on China's 2014 Environmental Protection Law, which has been widely regarded as the strictest environmental legislation in the country and officially took effect on 1 January 2015. Using this policy node allows us to distinguish the pre-reform institutional environment—characterized by weaker enforcement and stronger local discretion—from the post-reform stage marked by substantially enhanced legal constraints and monitoring capacity. The regression results in Table 15 show that, for sulfur dioxide, the pollution-enhancing effect of tax competition weakens noticeably after the reform, while the mitigating effect of environmental regulation remains significant across both periods. For haze, tax competition consistently increases pollution, whereas environmental regulation remains largely ineffective throughout. These findings suggest that stricter national environmental legislation can curb the most severe forms of ecological deterioration, yet it remains insufficient to offset the broader incentives driving local governments to prioritize economic competition, particularly in pollutants less responsive to administrative oversight.

6 Conclusion

Government is the decisive driver of China's economic operation, and there are government interventions behind many economic phenomena. As the leader of local governance, the subjective initiative of local governments plays a crucial role in many fields such as economic development and public services. Their behavioral motivation and decision-making incentives are key aspects that affect the effectiveness of environmental management. This study takes Chinese local governments as the research object, selects the provincial dynamic panel data of Chinese Mainland from 2007 to 2020 for empirical estimation, and confirms that local government intervention plays an important role in the environmental pollution management of the jurisdiction: Under a single task orientation, tax competition will exacerbate air pollution, while environmental regulations will alleviate air pollution. However, compared to haze pollution, local governments are more concerned about sulfur dioxide pollution, Under the premise of parallel tasks and limited resources, these two local strategies have a restraining effect on each other and show a nonlinear relationship. The ultimate result is that the positive effects of environmental regulations cannot reverse the negative effects of tax competition. This indicates that at present stage, competition among local governments in China still prioritizes economic growth, and although regional environmental quality is also an important aspect of concern for local officials, its weight is significantly lower than that of economic development. Nevertheless, they are not powerless in managing environmental pollution. We used instrumental variable and GMM estimation approach to address endogeneity issues such as potential omitted variables and bidirectional causality. Furthermore, we introduced a spatial model and confirmed that there is an obvious spatial correlation between local government behavior. In the promotion tournament and "beggar thy neighbor" competition mode, local governments transfer the negative impact of tax competition to other regions, while keeping the positive impact of environmental regulations within their jurisdiction.

7 Discussion

Based on the empirical findings, several policy implications emerge. First, since tax competition consistently exerts a stronger negative impact on air quality than the positive effects generated by environmental regulation, the central government should improve the incentive structure of the official assessment system by increasing the weight of environmental quality indicators and incorporating long-term ecological performance into cadre evaluation. Such reforms would shift local officials' incentives away from short-term growth-oriented competition and toward balanced governance.

Second, given the observed nonlinear interaction between tax competition and environmental regulation under resource constraints, strengthening intergovernmental fiscal coordination is essential. This includes improving the matching between fiscal decentralization and environmental responsibilities, expanding earmarked transfers for environmental governance, and reducing local governments' reliance on tax competition as a development strategy.

Third, the presence of significant spatial spillovers in tax competition but limited spillovers in environmental regulation suggests the need for cross-regional governance mechanisms. Establishing interprovincial environmental compensation schemes, unified regional emission standards, and tax-competition coordination platforms would help internalize pollution externalities and prevent beggar-thy-neighbor strategies.

Finally, while local governments are not powerless in pollution control, the results indicate that regulatory effectiveness varies. Strengthening environmental enforcement—through transparent disclosure, digital monitoring technologies, and stricter penalty schemes—can reduce the gap between policy attention and policy implementation, ensuring that environmental regulation exerts its intended effect.

This study analyzes the trade-off between economic growth and environmental protection in China, the largest developing country, over the past decade, and explores the effects of local government intervention and their competitive patterns. This may provide policy recommendations for central governments in China and developing countries to formulate fiscal, tax, and environmental policies. A related implication is that the empirical relationships documented in this paper should be understood within the institutional and economic context of that period. This study uses provincial panel data for China over the period 2007–2020. One important limitation is that the sample period ends before the full implementation of the "dual-carbon" strategy and the recent policy agenda of vigorously developing so-called "new-quality productive forces". As a result, the empirical analysis mainly captures the institutional environment in which traditional, resource- and energy-intensive industries still play a dominant role in shaping the interaction between intergovernmental tax competition, environmental regulation and air pollution. The findings should therefore be interpreted primarily as a characterization of the pre-transition stage rather than as a definitive statement about the new development paradigm emerging after 2020.

At the same time, the mechanisms highlighted in this paper—fiscal decentralization, promotion tournaments, and the policy trade-off between tax competition and environmental regulation under resource constraints—remain highly relevant, but their quantitative impact may evolve as industrial upgrading, digitalization and green technologies advance. Future research could extend the dataset to more recent years once consistent statistics become available, and explicitly incorporate indicators related to new-quality productive forces, such as the size of the digital economy and the intensity of green innovation, in order to examine how industrial transformation and technological progress reshape the relationship between tax competition, environmental regulation and air pollution. Another promising direction is to conduct city-level analyses or case studies of frontier regions where high tax revenues coexist with low pollution levels, so as to identify the boundaries of the mechanisms identified here and to refine the theoretical framework for the new stage of China's economic development.

7.1 Notes

1. Since China's 10th Five-Year Plan (2001-2005), "Population, Resources, and Environment" has been included as a separate chapter in the national development planning outline, with clear requirements for the control of air pollution and water pollution. Among them, sulfur dioxide emissions are included as a key indicator in the official environmental performance evaluation standards.
2. The environmental related vocabularies in provincial government work reports include environmental protection (*huanjingbaohu, huanbao*), pollution (*wuran*), energy consumption (*nenghao*), emission reduction (*jianpai*), pollution emission (*paiwu*), ecology (*shengtai*), green (*lvse*), low-carbon (*ditan*), air (*kongqi*), *COD* (*huaxuexuyangliang*), SO_2 (*eryanghualiu*), CO_2 (*eryanghuatan*), PM10, and PM2.5. Compared with the approach of Chen et al. (2018), this study uses more generalized vocabularies, so as to capture the government environmental regulation efforts more comprehensively.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

YC: Writing – original draft. ZL: Writing – original draft. DZ: Writing – review and editing.

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Supplementary material

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