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TAX COMPETITION, ENVIRONMENTAL REGULATION AND AIR POLLUTION - EMPIRICAL EVIDENCE FROM 278 CITIES IN CHINA

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Abstract

We assess the impact of tax competition and environmental regulation on air pollution. Based on the data of 278 cities from 2007 to 2016 in China, we systematically investigate the impact of tax competition and environmental regulation on air pollution by spatial Durbin model and instrumental variable. We find that the race to the bottom of tax competition has positive effects on air pollution and negative spatial spillover effects. Environmental regulation has negative effects on air pollution and positive spatial spillover effects. The race to the bottom of tax competition among local governments restrains the haze reduction effect of environmental regulation; environmental regulation fails to achieve the goal of guiding tax competition to promote local high-quality economic development. We further find that tax competition and environmental regulation have lower impact on air pollution in large and medium-sized cities than small cities, and the effect of environmental regulation has become more and more significant since 18th CPC National Congress in China.

Keywords: air pollution, environmental regulation, spatial Durbin model, tax competition

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1. Introduction

In the past 40 years of reform and opening up, China's economy had achieved rapid development, and China's GDP rose from 367.9 billion Yuan in 1978 to 82.71 trillion Yuan in 2017, accounting for 16 percent of the world economy up from 1.8 percent. However, along with the rapid economic development, the deterioration of environmental quality is increasingly prominent, especially the deterioration of air quality and frequent occurrence of haze. According to *China Environmental Status Bulletinin* 2017 disclosed, the air quality of 239 cities at prefecture-level and above was out of limits and serious contamination reached up to 2311 days in 2017. Air pollution problem had severely impeded China's economy high quality development, which was extremely urgent to solve the problem of haze pollution (Chen and Chen, 2018). Chinese government had already realized the seriousness of air pollution, the report of the 19th CPC National Congress also made it clear that china will continue to take action to prevent and control air pollution. The 2018 government work report also showed unprecedented determination and efforts to strengthen ecological environmental protection and control air pollution. In recent years, although the environmental quality of China has been significantly improved by strengthening the legal construction of environmental protection, strengthening environmental protection and prevention and other policy measures, it still fails to meet the people's growing demand for a beautiful ecological environment. The main reason was that China supervised environment by administrative territory management mode in the past, local governments were principal part of environmental

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management, while environmental governance was constrained by local economic development policy, local government officials were under pressure from both political promotion and local economic benefits maximization, they not only changed local environmental protection preference, but also reduced willingness to joint governance environment with surrounding areas (Chen and Pan, 2018). Especially after-tax reform in 1994, it formed the "promotion tournament model" of China's local officials with performance appraisal as the goal, economic development level significantly affected promotion and political status of local government officials. In order to attract investment, local government not only reduced effective tax rate, but also eased environmental regulation standard, which formed an environment-for-growth economic development model (Zhou, 2007). It can be seen that under the current mode of "promotion tournament model" with Chinese characteristics, the enhancement of air quality is not only about the governance of the environment itself, but also about the fundamental transformation of the mode of economic competition and cooperation between local governments. Therefore, exploring the impact of tax competition and environmental regulation on haze pollution will help to solve the puzzlement of local governments in protecting the environment and developing the economy (Gong et al., 2020). This paper will discuss the direct effect and spatial spillover effect of tax competition and environmental regulation on air pollution? At the same time, whether there is a synergistic effect? Is there heterogeneity?

2. Literature review and innovation

Domestic and overseas scholars had done a mass of research about tax competition and environmental pollution, they generally approved that low tax rate competition would trigger environmental pollution and high tax rate competition would be beneficial to improve environmental quality (Cremer and Gahvari, 2004). From international capital flow, tax competition induced cross border flow of international capital, which would increase environmental pollution of capital importing country (Hadjiyiannis et al., 2014). Li and Zhao (2017) used Chinese data to confirm that tax competition drove the government to adopt tax preferences to attract investment, which aggravated the ecological environmental pollution.

From the perspective of enterprise investment decision, Kim and Wilson (1997) pointed out that profit-maximization enterprises would migrate from high tax rate areas to low tax rate areas, which stimulated the government to further reduce tax rate, resulting in a trend of "race to the bottom", and inevitably increased environmental pollution in the places where enterprises moved. While Chirinko and Wilson (2017) researched and found that there was no "race to the bottom" of tax policy and it generally adopted "riding on a seesaw" competition strategy in America. Li and Luo (2016) researched and found that Chinese government also adopted differentiation strategy during tax competition process, such as adopting "optimal competition" for macro tax burden, adopting "inferior competition" for enterprise income tax, adopting "riding on a seesaw" strategy for value-added tax and environmental tax. Pi et al. (2014) pointed out that in order to promote local economic growth, local governments were keen to improve the environment for investment attraction through tax preferences and reduce the tax burden, leading to problems such as resource mismatch, overcapacity and environmental pollution. Zhou and Zhu (2018) indicated that due to spatial mobility of products, factors and pollutant, tax competition not only caused direct pollution for local environment, but also may cause indirect pollution for surrounding areas environment, environmental effect of tax competition should depend on a combination of direct effect and indirect effect. Bai et al.（2019）found that inter-regional tax competition not only brings negative influence to local environment, but also makes the environmental quality become worse in spatial correlation regions. These findings are of enlightening politic revelations to further standardize enterprise tax competition among local governments, and to promote the sustainable development both in economy and environment. Mele and Magazzino(2020) analyzed the relationship among iron and steel industries, air pollution and economic growth in China. They found that the relationship between economic growth and steel production is very strong in the first stage. Furthermore, the reduction of polluting emissions is linked to the principle of sustainable development. Udemba et al. (2020) found that higher energy consumption from fossil fuel had its environmental implication(s) especially in a high industrial economy like China. Environmental regulation has positive effect on pollution mitigation, Konisky (2007) disclosed that the government's economic development goals affected the strength of environmental governance, local governments tend to reduce environmental regulation standards to attract scare circulating capital and enterprises entering into local market, governments of taking easy environmental regulation standards competed with each other, resulting in inferior competition and aggravated environmental pollution. Li and Zhou (2005) emphasized that because an important index of Chinese government officials' promotion was relative economic index during their tenure, it ignored the reference of environmental index, which obviously exacerbated current local government officials loosing environmental regulation standards and incentive expectation of supervision. Huang (2017) indicated that local governments attracted investment by reducing environmental standards; officials could obtain the promotion benefits of economic growth and did not have to bear the consequences of destroying the environment, causing further deterioration of regional environmental pollution. Fan and Zhang (2018), Du et al. (2018, 2019) emphasized policy mix

of dynamic environmental tax and emission reduction subsidy rate would improve the motivation of enterprises' pollutants discharge reduction, and effectively control accumulation level of environmental pollution. Considering the rationalization and upgrading of industrial structure, Zhang et al. (2020) found that industrial structure could reduce haze pollution through the path of rationalization, but the role of the industrial structure upgrading had not been shown for the time being. Amann et al. (2020) found that effective implementation of the presently decided national pollution control regulations should allow further economic growth without major deterioration of ambient air quality, but will not be enough to reduce pollution levels in many world regions. Furthermore, Fredriksson and Millimet (2002) considered that because environmental pollutant is overflow, when local governments implemented more strict environmental governance standards, capital and enterprises would transfer to competitive regions, especially transfer to surrounding competitive regions, which still would result in environmental pollution for local areas.

Therefore, it prevented the motivation of local governments to improve environmental regulation standards, and it tended to take environmental governance policies imitating other regions, finally they paid for environmental pollution together (Woods, 2006). Shen et al. (2017) found in their study that there was indeed the phenomenon that pollution transferred to surrounding areas caused by environmental regulation, environmental regulation of pollution moving out areas not only improved the industry scale of pollution moving in areas, but also increased pollution level of pollution moving in areas. It can be seen that environmental regulation with externality not only has direct impact on environmental pollution of local areas, but also affects ecological environment of surrounding areas. Environmental regulation not only has a direct impact on environmental pollution, but also has an indirect impact on air pollution. Song et al. (2020) found that environmental regulation can directly alleviate environmental pollution. Additionally, technology innovation and industrial structure adjustment due to environmental regulation are also conducive to improving China's environmental situation. The direct effects of environmental regulation are greater than the indirect effects.

Literature on the impact of environmental governance and tax competition on high-quality economic development has made rich achievements. However, there is a typical fact that local governments in China are obviously competitive rather than cooperative in economic development and environmental governance. Literature has not yet systematically investigated it, and even ignores the fact that high-quality economic development needs the cooperation of regional governments. At present, tax competition and environmental regulation policies interact with each other among local governments. Under the new development concept, not only the local government needs to improve the intensity of environmental governance, but also the concept and mode of tax competition need to be changed. Tax competition has externality and pollutants have mobility. The pollutants produced by bottom-up tax competition will also cause environmental pollution in neighboring areas, which is not conducive to the coordinated green development of regional economy. Therefore, environmental governance can guide the green competition of tax, and there is a synergistic effect between environmental governance and tax competition on high-quality economic development.

Compared with existing literature, this paper has three contributions: first, based on the typical fact that Chinese local governments trend to adopt tax preferences and lower environmental governance standards under the background of "promotion tournament model" , this paper systematically investigates their influences on air pollution under the unified framework of tax competition and environmental governance; Second, The environmental regulation can relieve air pollution by the approach of controlling the entry and expansion of highly polluting enterprises, as the same time air quality can affect the choice of environmental regulation strategy. Therefore, there are endogenous problems between air pollution and proxy variables of environmental regulation. This paper constructs instrumental variable that can comprehensively reflect aspiration and intensity of environmental governance by prefecture-level city governments, and solves the endogenous problem of existing studies in finding proxy variables from environmental governance setting process and pollution control results; Third, this paper investigates heterogeneous effect of tax competition and environmental regulation in different city size and periods on air pollution.

3. Methodology and data

3.1. Specification of the econometric model

"Promotion tournament model" leads that local governments develop economy and compete with each other; taxation and environmental governance policy are instruments for local governments to compete for capital. Fredriksson and Millimet (2002) pointed out that the existence of interaction between tax competition and environmental governance strategy cannot be analyzed by traditional econometric models, and spatial econometric models are needed. Air pollution has spatial autocorrelation, and air pollution of local areas is also affected by tax policy and environmental regulation level of surrounding areas. Therefore, it is also necessary to introduce variables that reflect spatial spillover effect of tax competition and environmental regulation among local governments in the model. The spatial Durbin model considers the spatial dependence of independent variable and dependent variable at the same time, which can effectively solve the problem of

biased and inconsistent estimation results caused by the use of spatial lag model or spatial error model if there is spatial interaction effect in the real data generation process of variables (Shangguan, 2018). At the same time, the logarithmic function model can effectively resolve the influences of measurement unit, heteroscedasticity, skewness and extreme value (Wooldridge，2015). Therefore, this paper constructs the spatial Durbin model in the form of logarithm function as given by Eq. (1).

$$\begin{aligned}\ln PM2.5_{it} &= \rho W \ln PM2.5_{it} + \beta_1 \ln tax_{it} + \\ &+ \beta_2 \ln ere_{it} + \beta_3 \ln tax_{it} \cdot \ln ere_{it} \\ &\beta_4 W \ln tax_{it} + \beta_5 W \ln ere_{it} + \beta_6 X + a_i + \lambda_t + \nu_{it}\end{aligned} \quad (1)$$

where $PM2.5_{it}$ represents the average annual PM2.5 concentration of city i in year t, which is used to measure the level of air pollution; tax_{it} represents the average annual tax level of city i in year t, which is used to measure the tax competition behavior of local governments; ere_{it} represents the strength of environmental regulation of city i in year t, which is used to measure the environmental governance strategy of local governments; x represents correlated control variable setting into the model. Besides, in order to further alleviate omitted variable bias, this model also controls the fixed effect of city and time; a_i is city fixed effect, γ_t is time fixed effect, and ν_{it} is error term; ρ is the spatial autoregressive coefficient, and W is the geographical distance space weight. The size and sign symbol of β_1 and β_2 are direct effect, β_3 is interaction effect, β_4 and β_5 represent the spatial spillover effect of tax competition and environmental regulations.

3.2. Variables and data

3.2.1. Dependent variable

Air pollution (*PM2.5*)

The problem of air pollution with PM2.5 has drawn more and more attention from all walks of life, while literature always uses conventional air pollutant such as SO_2, CO_2 and PM10 to represent air pollution (Li et al., 2018). This paper selects the satellite monitoring PM2.5 concentration data published by the center for social-economic data and applications of Columbia University as the proxy for city air pollution for empirical research.

The data span is long and covers a comprehensive range, providing a solid data basis for accurately identifying the impact of tax competition and environmental regulation on air pollution.

3.2.2. Independent variables

Tax competition *(tax)*.

At present, Chinese tax rate is unified controlled by the central government (Zhou and Zhu, 2018). However, there are still a variety of indicators to measure tax competition in the literature the main reason is that local governments can reduce the local effective tax rate by tools of fiscal refunds, tax preferences and reducing the efficiency of tax collection and management. Based on the idea that Li and Zhao (2017) use effective tax rate to measure tax competition behavior among local governments, and because the typical fact that tax competition among local governments is basically "race to the bottom" driven by the mechanism of "promotion tournament model" in China, this paper uses the reciprocal of the ratio of total city industrial tax revenue to total industrial output value to measure tax competition behavior among local governments, and the data comes from *China City Statistical Yearbook*.

Environmental regulation (*ere*).

The choice of environmental governance strategy mainly depended on the local governments' aspiration of environmental governance, and there were differences in the intensity of environmental regulation in different regions, so it was relatively more comprehensive and objective to investigate the pollution governance results (Lanoie et al. ,2008). Considering the availability of data, this paper uses city SO2 removal rate, dust removal rate, wastewater discharge compliance rate and solid waste comprehensive utilization rate to construct calculation formula of environmental regulation as (Eq. 2):

$$ere_{it} = \frac{1}{4}\sum_{j=1}^{4}\left(\frac{Q_{ijt}}{\sum Q_{ijt}} \Big/ \frac{Y_{it}}{\sum Y_{it}}\right) \quad (2)$$

In Eq. (2), i represents city, t represents year, j represents discharged pollutants; *ere* represents environmental regulation intensity; Q is the amount of pollutants; $\sum Q_{ijt}$ is the total amount of pollutants; Y is the added value of industry; $\sum Y_{it}$ is the total industrial added value of all cities in year t. Bigger ere_{it} means the governmental environmental governance of city i is more strict in year t, and better effect of pollution treatment, and vice versa. The data comes from *China Statistical Yearbook on Environment* and *China City Statistical Yearbook*.

3.2.3. Control variables

In order to alleviate estimate bias caused by omitted variable, relevant city characteristic variables were controlled in the model: (1) *green* is the green coverage rate of city; (2) *traffic* is number of buses per 10000 people; (3) *info* is internet users per 10000 people; (4) *popu* is population per square kilometer. Since the mode of economic development is one of the significant reasons affecting air pollution, if the relevant factors of economic development cannot be effectively controlled, it will also lead to omitted variable bias and affect the reliability of the estimation results. Therefore, for further lower estimate bias caused by omitted variable, the model controls relevant economic variable in this paper. (5) Industrial structure *(industry*), which is expressed by the proportion of the added value of the secondary industry in GDP (%); (6) Financial development level

(finance), which is expressed by the per capita loan balance of financial institutions at the end of the year (Yuan); (7) Economic development level *(pgdp*), which is expressed by per capita GDP (Yuan); (8) Utilization of foreign capital *(fdi*), which is expressed by the ratio of foreign direct investment to GDP (%); (9) Consumption level *(consume*), which is measured by the city per capita annual consumption (Yuan). The above economic relevant variable data comes from *China City Statistical Yearbook*, and the city characteristic relevant data comes from *China Urban Construction Statistical Yearbook.* The data cannot be obtained directly from the yearbook, which is calculated by the relevant basic data of the yearbook. Per capita GDP is calculated according to price of the current year, in order to eliminate the influence of price change factors, this paper applies the resident consumption level index at the provincial level (2007=100) for the reduction treatment, and the actual foreign capital is converted into RMB by using the current year's exchange rate, all exchange rate data comes from the website of National Bureau of Statistics.

4. Empirical results and analysis

4.1. Spatial Durbin model regression analysis

The estimation spatial econometric model mainly adopts ML (maximum likelihood estimation), 2SLS (two-stage least square estimation), GMM (generalized method of moment) and FGLS (feasible generalized least square). Kapoor et al. (2007) pointed out that since FGLS has advantages of effectively overcoming inter-group heteroscedasticity, inter-group contemporaneous correlation and intra-group autocorrelation, it is more effective in estimating parameters of spatial Durbin econometric models. LR test shows that SDM model should not degenerate into SAR model or SEM model, indicating that SDM model selected above based on theoretical analysis is appropriate, and Hausman test results show that fixed effect is superior to random effect. Therefore, FGLS is adopted for regression of spatial Durbin model with fixed effect in this paper.

Table 1 reports the results of spatial weight estimation based on geographical distance. Columns (1) and (2) are the estimator results without and with interaction terms respectively. From the estimator results of Columns (2) we can see that when relevant city characteristic and economic variables are controlled, the spatial autocorrelation coefficient (ρ) is significantly positive at the significance level of 1%, which illustrates that city air pollution has strong spatial autocorrelation in China. Tax competition has significantly positive influence on PM2.5 of local area, which means the average concentration of PM2.5 will increase 0.861% if the tax competition increases 1%. Tax competition of local government derived from "promotion tournament model" tends to reduce effective tax rate, which leads to resource mismatch and low efficiency, reduces the market stealing cost of working capital, and restrains the motivation of enterprises to innovate and the willingness of adopting advanced technology to transform and upgrade, it is not good for haze prevention and treatment. The estimated coefficient of environmental regulation is significantly negative at the significance level of 1%, and every 1% increase in environmental regulation intensity can reduce the PM2.5 concentration by 1.084 % on average. The estimated coefficient of interaction terms between tax competition and environmental regulation is negative, but not significant. It illustrates that tax competition of local governments will aggravate local air pollution, improving environmental regulation intensity will restrain air pollution, but when improving environmental regulation intensity and tax competition at the same time, tax competition restrains the improvement effect of environmental regulation on air pollution governance, and the comprehensive effect cannot achieve the goal of guiding local government tax benign competition to promote high-quality economic development by environmental regulation policies. The regression coefficient of W*Ln*tax* is significantly negative at the significance level of 10%, while the regression coefficient of W*Ln*ere* is significantly positive at the significance level of 1%, which illustrates that tax competition of local governments has negative effect on air pollution of surrounding areas, improving environmental regulation intensity will lead that polluting enterprises transfer to surrounding areas, which increases the pollution of surrounding areas.

From the estimation results of control variable, the estimated coefficient of city green and basic traffic is negative at the significance level of 5%; the estimated coefficient of informational level is negative at the significance level of 10%; the estimated coefficient of population density is positive at the significance level of 1%. It illustrates that the optimization of city living environment is conducive to reduce local air pollution. Industrial structure, economic development level and utilization of foreign capital are positive at the significance level of 5%, and the estimated coefficient of consumption level and financial development is positive, but not significant. It illustrates that there is still an extensive development mode of exchanging environment for growth in China's regional economic development. Actively promoting industrial transformation and upgrading and developing green economy are important ways to solve air pollution (Gong et al., 2019a; 2019b).

Considering that it takes some time for tax competition and environmental governance strategy to have an impact on local and neighboring air pollution through the market mechanism, and local area also refers to strategy of surrounding areas when formulates local environmental governance and tax competition strategy, in order to alleviate estimate bias caused by hysteresis effect of tax competition and environmental governance strategy, tax competition and environmental regulation will be lag one delayed

for a period and then regression. Regression results are reported in the columns (3) - (4) of Table 1, which corresponds to columns (1) - (2). The positive impact of tax competition and the negative impact of environmental regulation on air pollution still exist, and the significance is basically unchanged. In addition, the coefficients of other control variables are basically consistent with the estimated results in the current period.

4.2. Endogenous environmental regulation and estimation of instrumental variable

When study how environmental regulation affects air pollution, its endogenous is a matter that has to be discussed. Since the number of environmental pollution governance personnel, the cost of management and the amount of pollutants discharged are all endogenous to the local environmental quality, the adoption of its agency environmental governance intensity will lead to errors in the estimation results. To be specific, on the one hand, environmental regulation can relieve air pollution by the approach of controlling the entry and expansion of highly polluting enterprises; on the other hand, it can affect the choice of environmental governance strategy intensity through affecting local governments' willingness to deal with air pollution when air pollution is serious. Therefore, we need find appropriate environmental regulation instrumental variable to solve the problem of estimate bias caused by endogenous

At present, the main methods of environmental regulation in China are to issue administrative orders on energy conservation and emission reduction, formulate environmental protection regulations and promulgation of environmental protection laws and regulations. Drawing on the ideas of Chen et al. (2018), this paper chooses environment-related vocabulary proportion in the provincial government work reports as the instrumental variables of environmental regulation.

Provincial government work report is a programmatic policy document to plan and guide local governments to carry out related work. Therefore, environment-related vocabulary proportion in the report can comprehensively embodiment the local governments' aspiration and intensity of environmental governance.

Table 1. Regression results of SDM model based on FGLS

Variable	***Dependent variable: Ln PM2.5***		***Dependent variable: Ln PM2.5***	
	(1)	***(2)***	***(3)***	***(4)***
	Independent variable: current		***Independent variable: lag one***	
Ln*tax/ L.*	0.802***	0.861***	0.801***	0.864***
	(0.066)	(0.075)	(0.061)	(0.066)
Ln*ere/ L.*	-1.168***	-1.084***	-1.087***	-1.019***
	(0.310)	(0.320)	(0.320)	(0.290)
Ln*tax**Ln*ere/ L.*		-0.656		-0.661
		(0.610)		(0.620)
W*Ln*tax/ L.*	-0.540*	-0.580*	-0.680***	-0.760****
	(0.290)	(0.320)	(0.230)	(0.250)
W*Ln*ere/ L.*	0.670**	0.690***	0.810**	0.950***
	(0.310)	(0.260)	(0.370)	(0.34)
Ln*green*	-0.390	-0.610**	-0.620	-0.840**
	(0.480)	(0.290)	(0.870)	(0.360)
Ln*traffic*	-0.670*	-0.590**	-0.650	-0.470***
	(0.360)	(0.260)	(0.610)	(0.230)
Ln*info*	-0.012	-0.015*	-0.013	-0.018*
	(0.014)	(0.010)	(0.018)	(0.013)
Ln*popu*	0.170***	0.180***	0.160***	0.190***
	(0.061)	(0.064)	(0.067)	(0.076)
Ln*industry*	0.190**	0.240**	0.170**	0.196**
	(0.080)	(0.110)	(0.070)	(0.083)
Ln*fdi*	0.360*	0.390**	0.430*	0.470**
	(0.190)	(0.180)	(0.270)	(0.230)
Ln*pgdp*	0.281*	0.270**	0.301	0.291**
	(0.170)	(0.130)	(0.380)	(0.142)
Ln*finance*	0.004	0.007	0.039*	0.024
	(0.031)	(0.033)	(0.028)	(0.031)
Ln*consume*	0.035	0.041	0.039*	0.029
	(0.049)	(0.047)	(0.035)	(0.031)
ρ	0.558***	0.545***	0.548***	0.546***
	(0.134)	(0.135)	(0.129)	(0.132)
City fixed effect	Y	Y	Y	Y
Time fixed effect	Y	Y	Y	Y
Observations	2780	2780	2502	2502

*Notes: ***significance at 1%*;** significance at 5% ;* significance at 10%. Heteroskedasticity -robust standard errors clustered by city are in parentheses. L. represents corresponding variable of lag one*

In this paper, the work reports of 31 provincial governments in China from 2007 to 2016 were collected by hand, and their contents were processed by word segmentation, so as to calculate the proportion of environment-related words in the total vocabulary. Compared with the instrumental variables constructed by Chen et al. (2018), the choice of environment-related vocabulary in this paper is more comprehensive, so it is can more accurately represent the local governments' aspiration and intensity of environmental governance. Using environment-related vocabulary proportion in the provincial government work reports to represent the prefecture-level city governments' aspiration and intensity of environmental governance, which can remit the problem of endogenous, but it cannot effectively reflect the heterogeneity of prefecture-level city governments' aspiration and intensity of environmental governance. Because the impact of the intensity and willingness of environmental governance of provincial governments on lower-level governments will vary with the proportion of industries in different prefecture-level cities, for prefecture-level cities with a higher proportion of industry, the intensity and willingness of environmental governance of provincial governments has more influences on the choice of prefecture-level cities governments environmental governance strategy. Based on the above logic, this paper innovatively uses the proportion of total industrial output value of above the scale of prefecture-level cities in the whole province multiplied by the proportion of environment-related vocabulary in the provincial governments work report to construct the instrumental variables of city environmental governance finally.

The instrumental variables of environmental regulation of prefecture-level cities governments constructed in this paper can well meet the logical assumption that the instrumental variables are exogenous: first, provincial governments usually report their work at the beginning of the year, while environmental pollution problems run through the whole year, avoiding endogenous problems caused by reverse causation. Second, the behavior of prefecture-level cities governments usually does not affect the decision of provincial governments, instrumental variables of environmental regulation is constructed by the of provincial government work report, other variables in the model are the level of prefecture-level cities, which further alleviates the endogenous problem of reverse causation.

Therefore, the instrumental variables and endogenous variables (environmental regulation) constructed in this paper are highly correlated, and do not reflect explained variable directly. Based on the estimation results of instrumental variables reported in the columns (1) of Table 2, the core variables are similar to the regression results reported in Table 1 in terms of the direction and significance of air pollution. But quantitatively, compared with the preliminary regression, the estimated value of the environmental regulation coefficient is significantly increased, which indicates that endogenous problems will lead to the underestimation of the negative effect of environmental governance policies on air pollution.

Ceteris paribus, every 1% increase in environmental governance intensity can reduce the PM2.5 concentration by 1.327% on average. The estimated value of the tax competition coefficient is significantly decreased, which indicates that endogenous problems will lead to the overestimation of the positive effect of tax competition on air pollution. Ceteris paribus, the average concentration of PM2.5 will increase 0.604% if the level of tax competition increases 1%. Instrumental variables regression illustrates that environmental regulation obviously reduces the cities' air pollution in China, which means that implementing effective environmental governance policies can achieve the goal of haze prevention and treatment.

4.3. Extension analysis: heterogeneity of city scale and time period

Since the city scale or time period are different, local governments are vary with the formulation and implement of taxation and environmental governance policies, this paper estimates the model with the constructed instrumental variables, and discusses whether the heterogeneity of city scale or time period leads to the different impacts of local government tax and environmental regulation on air pollution.

Compared with the estimation results in the columns (1) of Table 2, we can find that the positive effect of tax competition on the air pollution of large and medium-sized cities is obviously higher than that of small cities. Considering the allocation effect，large and medium-sized cities is more attractive for capital than small cities at the same tax level. The absolute value of the estimated coefficient of environmental regulation in large and medium-sized cities is smaller than that in small cities, that is to say, increase the intensity of environmental governance by the same unit, the effect of air pollution control in small cities is more significant than that in large and medium-sized cities. The main reason is that given same aspiration and intensity of environmental governance of large and medium-sized cities and small cities, small cities can control pollution sources more directly and effectively than large and medium-sized cities through administrative means such as order and accountability.

The estimated coefficient of interaction terms between tax competition and environmental regulation of large and medium-sized cities is negative, but not significant, which indicates that when implementing same taxation and environmental regulation, since enterprises in small cities response more sensitive to taxation, the same policy works better for haze treatment of small cities.

Table 2. Instrumental variables estimator and heterogeneous regression results

Variable	*Dependent variable:ln pm2.5*	*Dependent variable:ln pm2.5*		*Dependent variable:ln pm2.5*	
	IV Estimator	*City heterogeneity*		*Time heterogeneity*	
	（1）	*（2）Large and medium -sized cities*	*（3）Small cities*	*（4）2007-2011*	*（5）2012-2016*
Ln*tax*	0.604***	0.810***	0.470***	0.610***	0.510**
	(0.183)	(0.234)	(0.113)	(0.246)	(0.231)
Ln*ere*	-1.327***	-1.109***	-1.441***	-1.095***	-1.547***
	(0.280)	(0.221)	(0.293)	(0.316)	(0.291)
Ln*tax**Ln*ere*	-0.760*	-0.660	-0.810**	-0.560	-0.880**
	(0.440)	(0.430)	(0.401)	(0.430)	(0.410)
W*Ln*tax*	-0.790***	-0.571*	-0.910***	-0.780***	-0.390*
	(0.310)	(0.320)	(0.240)	(0.220)	(0.230)
W*Ln*ere*	0.740***	0.461*	0.943***	0.760***	0.530**
	(0.220)	(0.254)	(0.284)	(0.210)	(0.240)
ρ	0.556***	0.584***	0.598***	0.563***	0.587***
	(0.126)	(0.127)	(0.122)	(0.131)	(0.123)

*Notes: ***significance at 1%*;** significance at 5% ;* significance at 10%*

The absolute value of regression coefficient of the spatial lag term of tax competition and environmental regulation in small cities are both larger than that in large and medium-sized cities, which illustrates that the policy of environmental regulation and tax in small cities are more externality and spatial demonstration than that of large cities.

Regression results of time period heterogeneity are reported in the columns (4) - (5) of Table 2, which shows that the influence of tax competition on air pollution has not significantly changed, but the influence of environmental regulation on air pollution has significantly improved since 18th CPC National Congress. The main reason is that the Party central committee and the State have incessantly improved intensity of environmental governance and increased strength of air pollution governance, issued policies that local governments should be held accountable for environmental issues, and improved local governments' willingness to deal with air pollution and the efficiency of implementing environmental policies since 18th CPC National Congress. The estimated coefficient of interaction terms between tax competition and environmental regulation become significant, which illustrates that it can introduce local government tax benign competition by environmental governance policies, and then guide the local government economy from extensive development mode to high-quality development mode. The regression coefficient of the spatial lag term of tax competition and environmental regulation are both significantly smaller, which illustrates that the joint prevention and control mechanism of air pollution has worked.

4.4. Robustness test

To ensure the reliability of the conclusion, a series of robustness tests were conducted based on the regression results of the instrumental variables in column (1) of Table 2, which were reported in Table 3. Columns (1) - (3) are robustness tests based on geographical distance weight. In order to make the estimated samples of the model comparable, further eliminating the samples of cities above the prefecture level, the estimated results are reported in the column (1) of Table 3, the size and direction of the influences of tax competition and environmental regulation on local air pollution of estimated samples of only prefecture-level cities retained are basically consistent with the regression results of the whole sample, only its spatial spillover effect has increased, which also illustrates that the mutual learning and imitation effect of policies among small cities are stronger, but not significant, which illustrates that the estimated results of whole sample are robustness. In order to survey the influences of tax competition and environmental regulation outlier on regression results, further eliminating the highest and lowest 0.5% samples of tax competition and environmental regulation, the estimated results are reported in the column (2) of Table 3, though the estimator of core variable coefficient has decreased, but not significant, and its significance level is unchanged, which proves that the conclusion in this paper is robustness. To test the sensitivity of regression results to sample data, bootstrap is used for re-estimated, column (3) of Table 3 shows the estimated results of 1000 sample selections. The comparison shows that the effect of tax competition and environmental regulation on air pollution are still significant, therefore, the parameter values and significance of the related variables estimated above are robustness.

All the above are adopted geographical distance space weight to study the influence and spatial spillover effect of local governments' tax competition and environmental regulation on air pollution, to investigate the influence of space weight on model regression results, further estimating the above related robustness test method by adjacent space weight, the regression results are reported in the column (4)-(6) of Table 3, compared with results in the column (1)-(3), we can find that the effect direction of tax competition and environmental regulation coefficient is unchanged, and its coefficient size and significance level also are basically unchanged, which illustrates that the estimated results adopted geographical distance space weight above are robustness.

Table 3. Robustness test results

Variable	*Dependent variable:Ln PM2.5*			*Dependent variable:Ln PM2.5*		
	（1）	*（2）*	*（3）*	*（4）*	*（5）*	*（6）*
	Geographical distance space weights			*Adjacent space weight*		
	Prefecture-level cities	*Outliers*	*Bootstrap*	*Prefecture-level cities*	*Outliers*	*Bootstrap*
Ln*tax*	0.715***	0.616***	0.641***	0.780***	0.650***	0.659***
	(0.190)	(0.154)	(0.172)	(0.237)	(0.240)	(0.236)
Ln*ere*	-1.331***	-1.307***	-1.316***	-1.329***	-1.209***	-1.231***
	(0.280)	(0.264)	(0.250)	(0.290)	(0.310)	(0.293)
Ln*tax***ere*	-0.670*	-0.560*	-0.590*	-0.665**	-0.538*	-0.620*
	(0.425)	(0.310)	(0.336)	(0.330)	(0.320)	(0.350)
W*Ln*tax*	-0.850***	-0.761***	-0.710***			
	(0.230)	(0.220)	(0.210)			
W*Ln*ere*	0.840***	0.710***	0.830***			
	(0.230)	(0.210)	(0.260)			
W*Ln*tax*				-0.715***	-0.870**	-0.697**
				(0.203)	(0.310)	(0.260)
W*Ln*ere*				0.791***	0.620**	0.615**
				(0.230)	(0.310)	(0.290)
ρ	0.589***	0.542***	0.534***	0.504***	0.517***	0.507***
	(0.026)	(0.036)	(0.027)	(0.032)	(0.029)	(0.028)

*Notes: ***significance at 1%*;** significance at 5% ;* significance at 10%*

5. Conclusions

Making Chinese cities at prefecture-level and above as the sample, this paper systematically surveys the influences of local governments' tax competition and environmental regulation on air pollution by the constructed spatial Durbin model and instrumental variables. We find that the tax competition has positive effect and negative spatial spillover effect on air pollution of local areas and environmental regulation has significantly negative effect and positive spatial spillover effect on haze pollution of local areas, tax competition restrains the effect of environmental governance policies on air prevention and treatment, failing to achieve the purpose of guiding local government tax benign competition by environmental regulation. Further expanding the findings, the influences of tax competition and environmental regulation on air pollution treatment of large and medium-sized cities are obviously lower than that of small cities, and environmental regulations have been increasingly effective in preventing and controlling air pollution since 18th CPC National Congress.

To achieve the vision of sustainable development, it not only requires a combination of local governments' tax preferences and environmental governance policies, but also needs central governments introduce local areas change mode of economic competition and encourage local governments implement a win-win policy of benefiting themselves and enriching their neighbors.

The State should further guide tax competition behavior among local governments and regulate its jurisdiction, reduce tax preferences behavior that is detrimental to environmental improvement, and introduce local government tax competition from "race to the bottom" to "race to the top". At the same time, it should weaken the evaluation of single economic indicators; improve the scientific and effective comprehensive evaluation system including environmental indicators and the diversified promotion system for local officials.

The efforts of single areas to control and prevent air pollution are not significant because of the spatial spillover characteristics, therefore, under the constraints of the overall regional environment, local governments need plan and implement the synergy program of air pollution treatment, establish the joint system of intraregional environmental pollution monitor, supervision, law enforcement and early warning, and clarify the mechanism of intraregional interests coordination and pollution compensation.

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