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Tax Competition, Spatial Effect, and Environmental Pollution: An Empirical Analysis of the GTWR Model

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Abstract:
This paper draws on the Chinese 31 provincial panel data from 2000 to 2017 and then uses the GTWR model to empirically test the spatial effect of tax competition on regional environmental pollution. The estimated results show that there exists significant spatial heterogeneity of effects of tax competition on regional SO2 discharge and wastewater discharge. In addition, the paper uses the LISA method to measure the spatial correlation pattern of estimated coefficients of the GTWR model, which finds that significant spatial dependence exists on the effects of tax competition on regional environmental pollution. The effects of tax competition on regional SO2 discharge present a 'low-low' spatial correlation pattern. There is a depression effect of impact in the regional spatial pattern, namely, the provinces with smaller impacts are close to each other and gather together in space. The effects of tax competition on regional wastewater discharge present a 'high-high' spatial correlation pattern. There is a highland effect of impact in the regional spatial pattern, namely, the provinces with greater impact are close to each other and gather together in space.

Keywords: *Tax competition, Environmental pollution, spatial effect, GTWR model*

1. Introduction

Since the reform and opening up for more than 40 years, China's rapid economic development is at the cost of environmental pollution. On the other hand, environmental problems caused by the extensive economic growth model characterized by 'high input, high consumption and high pollution' have become a serious and persistent disease in China's current public governance field.

Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China highlights promoting the all-round green transformation of economic and social development. At the same time, the report of the 19th National Congress of the Communist Party of China (CPC) also explicitly proposed promoting green development, accelerating the establishment of a legal system and policy guidance for green production and consumption. While emphasizing green development and harmonious coexistence between humans and nature, China's government work report in 2022 also proposes optimizing and implementing tax reduction policies to ensure market players enjoy them to the fullest. Taxation plays a guiding role in regulating environmental pollution emissions and green economic development under the background of economic transformation with green and high-quality development as the goal. Due to the strategic demand of actively promoting ecological civilization construction, various local governments have established the assessment goal of 'green GDP' and adopted environmental governance means, including tax policy tools. The tax competition behavior of local governments has appeared with new characteristics and new trends. However, what is the mechanism of tax competition between local governments on environmental pollution emissions? Do the degree of tax competition and behavior alienation affect environmental pollution emissions, and to what extent? How to optimize the tax competition mechanism to regulate the environmental pollution emissions to alleviate the insufficient carrying capacity of resources and the environment, improve the regional ecological elastic capacity and cultivate new economic growth power sources? The research on the above issues has important theoretical and practical significance for promoting China's tax reform, promoting energy conservation and emission reduction, and realizing the high-quality development of a green economy.

In view of the above, based on the background of economic transformation with green and high-quality development as the goal and the strategic demand of actively promoting ecological civilization construction, this paper applies panel data of 31 provinces in China from 2000 to 2017, tests the spatial heterogeneity effect of tax competition on environmental pollution with the use of the geographically and temporally weighted regression (GTWR) model. Then the spatial correlation pattern of the estimated coefficients of the GTWR model is measured by local indicators of spatial association (LISA). Finally, the paper puts forward the rectification and optimization countermeasures of the tax competition mechanism that is compatible with the high-quality development goal of the green economy.

2. Model Specification, Variables Selection, and Estimation Method

2.1. Model Specification

Tax competition among local governments directly or indirectly affects the environmental pollution emissions among regions from the following two aspects:

On the one hand, tax competition affects environmental pollution emissions by affecting the capital introduction, the ingress and egress of polluting enterprises, and the strength of environmental regulation in various areas.

On the other hand, tax competition influences environmental pollution emissions by influencing the flow of resource factors between industries and the cost of pollution emissions of enterprises. In order to measure the effect of tax competition between local governments in China on environmental pollution emissions, the econometric model is initially expressed as follows:

$$P_{it} = \beta_1 TAX_{it} + \beta_2 POP_{it} + \beta_3 URBAN_{it} + \beta_4 IS_{it} + \beta_5 FI_{it} + \beta_6 PGDP_{it} + \varepsilon_{it} \quad (1)$$

In formula (1): i indicates the province while the t indicates the year respectively, ε_{it} is the random disturbance term, *P* is the emission level of environmental pollution (in the paper, SO2 emission intensity and wastewater emission are selected as measurement indicators), the *TAX* is the tax competition, *POP* is population density, *URBAN* is the level of urbanization, *IS* is the industrial structure, *FI* is fixed assets investment, *PGDP* is the level of economic development, β_1, β_2, β_3, β_4, β_5, β_6 are the estimated coefficients of each variable respectively.

2.2. Variables Selection

This paper selects panel data covering the period from 2000 to 2017 in China's 31 provinces and regions (the author cannot get the statistical data of Hong Kong, Macao, and Taiwan. So they are not included in this paper) as the research samples. Related data are mainly from 'China Statistical Yearbook', 'China Fiscal Yearbook', 'China Tax Yearbook', 'China Environmental Statistical Yearbook', and 'Statistical Yearbook of provinces'. Natural logarithms are taken for all variables to eliminate heteroscedasticity and enhance index data stationariness. The definition and measurement of specific variables are shown in table 1.

Variable	Code	Definition and Measurement
Environmental pollution emissions	SO2/ WATER	In the paper, waste gas and wastewater with the characteristics of trans-regional spatial spillover are selected as the main pollutants to measure regional environmental pollution emissions. Firstly, China's current traditional energy consumption structure based on coal and oil determines that SO2 is one of the main sources of air pollution. Therefore, the paper selects the SO2 emission intensity of various provinces and regions as the waste gas emission index, which is mainly measured by the SO2 pollution emission per unit of GDP (Xiaomei Hu, 2018) [1]. Secondly, the wastewater discharge index is characterized by selecting the proportion of wastewater discharge of each province and region in the GDP.
Tax competition	*TAX*	The impact of tax competition on environmental pollution emissions is mainly reflected in the guiding role of inter-regional differences in tax burden levels on the spatial flow of resource elements. It is expressed in this paper by the proportion of tax revenue in the GDP of each province and region (Jie Liu & Wen Li, 2013) [2].
The population density	*POP*	The continuous increase in population will aggravate the environmental burden. In the paper, the population density index of each province and region in 'China Statistical Yearbook' is used to directly represent the population density.
Level of urbanization	*URBAN*	With the acceleration of urbanization, the urban population continues to increase, aggravating environmental pollution to some extent. In the paper, the proportion of the urban population in the total population of each province and region is used to measure the urbanization level. The specific indicator is constructed as follows: Urbanization level=the number of urban population in each province and region/the total population in each province and region in the same year
The industrial structure	*IS*	As a major source of environmental pollution emissions, the higher the proportion of the added value of the secondary industry in GDP, the more industrial pollutants will be discharged, thus exacerbating the cross-regional emissions and spillover of environmental pollution. The paper uses the proportion of the added value of the secondary industry in GDP to represent the industrial structure.
Fixed asset investment	*FI*	With the increase of social fixed assets investment, it is necessary to increase investment and construction, which will impact the environment. The paper uses the proportion of fixed asset investment in GDP to represent the index.
Level of economic development	*PGDP*	In the paper, per capita GDP is used to represent the level of economic development. The specific index construction method is as follows: per capita GDP= GDP of each province and region/total population of each province and region at the end of the year.

Table 1: Selection, Definition, and Measurement of the Variables

2.3. Estimation Method

Due to the heterogeneity of resource factor endowment, economic development level, spatial location conditions, historical development stage, and other factors among regions in China, the effect of tax competition on regional environmental pollution will inevitably be affected by these spatial heterogeneity factors. Therefore, the possibility that the independent variable coefficient is non-constant must be considered in the quantitative regression (Danlin Yu and Bingyang Lv, 2009) [3]. The traditional ordinary least square (OLS) regression model only estimates the average or global parameters. The estimated parameters are fitted values and do not change with the changes of the sample individuals. Therefore, the estimated constant parameters cannot reflect the spatial instability and the differences in environmental pollution emissions in different regions, resulting in limited theoretical and policy significance of the research results and conclusions.

In order to overcome this defect, the paper will use the GTWR model to investigate the effect of tax competition on regional environmental pollution, considering not only the spatial correlation of various explanatory variables, including tax competition, population density, urbanization level, industrial structure, fixed asset investment, economic development level, but also the heterogeneity of various impact factors in different regions. The parameters estimated for different regional samples are variable, and the theoretical significance of heterogeneity and the policy value of differentiation are more obvious (Yuming Wu, 2013)[4]. The general expression of the GTWR model is as follows:

$$Y_i = \beta_0(\mu_i, v_i, t_i) + \sum_k \beta_k(\mu_i, v_i, t_i) X_{ik} + \varepsilon_i \quad (2)$$

In formula (2): (μ_i, v_i, t_i) is the spatio-temporal latitude and longitude coordinates of the sample point i (as a spatio-temporal geographical weighting). The spatial distance between the sample point i and sample point j can usually be calculated by using the longitude and latitude data of the administrative centers of various provinces and regions, t is time distance. $\beta_k(\mu_i, v_i, t_i)$ is the estimated value of continuous function $\beta_k(\mu, v, t)$ at the sample point i, and its estimation method is as follows:

$$\hat{\beta}(\mu_i, v_i, t_i) = [X^T W(\mu_i, v_i, t_i) X]^{-1} X^T W(\mu_i, v_i, t_i) Y \quad (3)$$

In formula (3): $W(\mu_i, v_i, t_i)$ is the spatial weight matrix, which is determined by the spatial weight function. There are three methods to calculate the spatial weight function, including gaussian distance weight, exponential distance weight, and cubic distance weight (LeSage, 2004)[5].

As for the selection criteria of bandwidth, CV method (cross confirmation method) is adopted in the paper. The specific calculation formula is as follows:

$$\text{CV} = \sum_i^n \left[Y_i - \hat{Y}_i(b) \right]^2 \quad (4)$$

In formula (4): $\hat{Y}_i(b)$ is the fitted value of Y_i, and when CV reaches the minimum value, the corresponding value of *b* is the corresponding bandwidth. Different spatial distance weight functions are used to obtain different bandwidths. When the AIC (Akachi information criterion) value of the GTWR model is the minimum, the *b* value is the optimal bandwidth at this point (Fotheringham et al., 1996) [6].

3. Econometric Regression and Empirical Analysis

3.1. Analysis of GTWR Model Regression Results

In the paper, the empirical operation of the GTWR model is completed with the help of Matlab software, using adaptive bandwidth for regression analysis, and comparing the regression results obtained by the actual calculation with the OLS model estimation results. The paper presents the regression estimation results of the GTWR model and OLS model based on panel data of 31 provinces in China from 2000 to 2017, which are shown in table 2.

Pollutants	Model	AIC Value	R^2
lnSO2	GTWR	5543.2728	0.8358
	OLS	7099.3247	0.2619
lnWATER	GTWR	-6395.6573	0.9889
	OLS	-1723.9611	0.7127

Table 2: Comparison of the Results between the GTWR and OLS Estimation Models

As shown in table 2, the R^2 (0.8358 and 0.9889) of the GTWR model is much higher than the R^2 (0.2619 and 0.7127) of the OLS model, indicating that the GTWR model has higher goodness of fit than those of the OLS model. The AIC values of the GTWR model (5543.2728 and-6395.6573) are much lower than those of the OLS model (7099.3247 and-1723.9611). According to the evaluation criteria of Fotheringham et al. (1996) [6], as long as the difference between the two index values is greater than 3, the GTWR model is superior to the OLS model. Therefore, it is more scientific to select the GTWR model to explain the spatial heterogeneity of various influencing factors of regional environmental pollution to more accurately reveal the spatial heterogeneity effect of tax competition on regional environmental pollution.

Table 3 reports the quintile estimation results of regional environmental pollution affected by factors such as tax competition, population density, urbanization level, industrial structure, fixed asset investment, and economic development level. There are significant differences in regression fitting values of different quintiles.

Pollutants	Variables	Minimum	Lower Quartile	Median	Upper Quartile	Maximum
lnSO2	lnTAX	-9.7216	-0.1226	0.1753	0.5759	5.9177
	lnPOP	-26.4308	0.0634	0.6132	2.0643	15.9368
	lnURBAN	-55.5911	-3.2476	-0.5794	0.1348	10.5170
	lnIS	-20.3487	-0.8748	-0.0376	0.4700	14.7878
	lnFI	-12.1411	-0.4480	-0.1367	0.3500	8.4997
	lnPGDP	-7.3004	-1.0972	-0.3539	-0.0368	5.9336
lnWATER	lnTAX	-1.1571	-0.1042	-0.0297	0.0400	0.6792
	lnPOP	-1.0883	-0.0013	0.0643	0.2354	2.4582
	lnURBAN	-1.2807	-0.3034	-0.1337	-0.0022	0.7272
	lnIS	-1.5614	-0.1774	-0.0672	0.0239	1.0979
	lnFI	-1.2907	-0.1114	-0.0450	0.0124	0.8354
	lnPGDP	-0.5115	-0.1321	-0.0523	-0.0016	0.2007

Table 3: GTWR Quintile Estimation Results of Influencing Factors of Regional Environmental Pollution

According to the quintile regression analysis results of the GTWR model in table 3, the parameter estimates of different quintiles are quite different, indicating that the influence of each explanatory variable on the different samples in the region is heterogeneous. It means that individual differences cannot be ignored in factors such as inter-regional tax competition, population density, urbanization level, industrial structure, fixed asset investment, and economic development level. This difference leads to significant heterogeneity in the spatial distribution of regional environmental pollution, which leads to significant interdependence of environmental pollution in space, thus forming a 'local club group' of environmental pollution. Furthermore, the spatial non-stationarity of the marginal impact effect of specific variables on regional environmental pollution can be seen from the coefficient variation range and quintile difference in table 3, which further quantifies the local spatial heterogeneity of regional environmental pollution.

Figures 1, 2, 3, and 4, respectively, show the spatial distribution of the estimated coefficients of the GTWR model of the impact of tax competition (*lnTAX*) on environmental pollution (*lnSO2/lnWATER*) in 2000 and 2017.

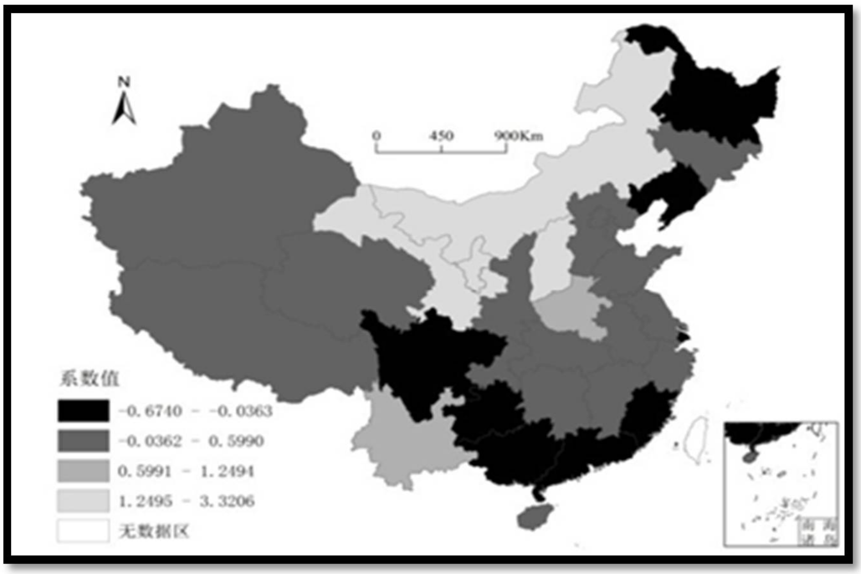

Figure 1: Spatial Distribution of Tax to SO2 Coefficient in 2000

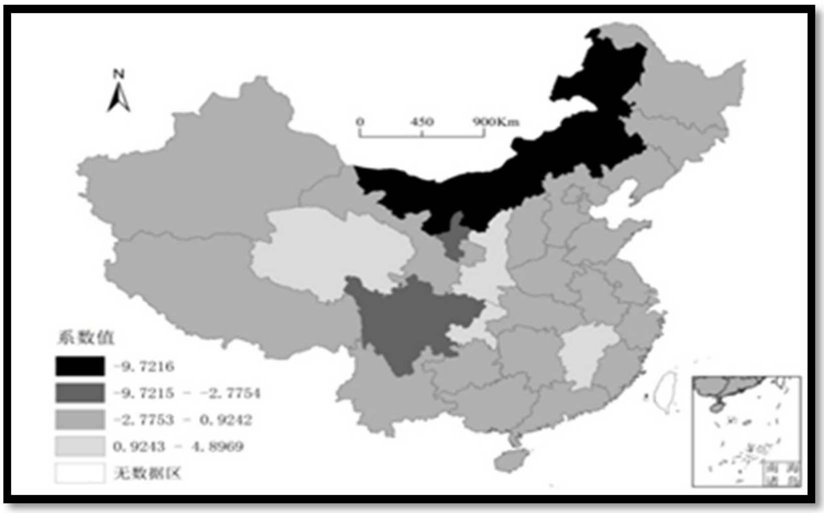

Figure 2: Spatial Distribution of Tax to SO2 Coefficient in 2017

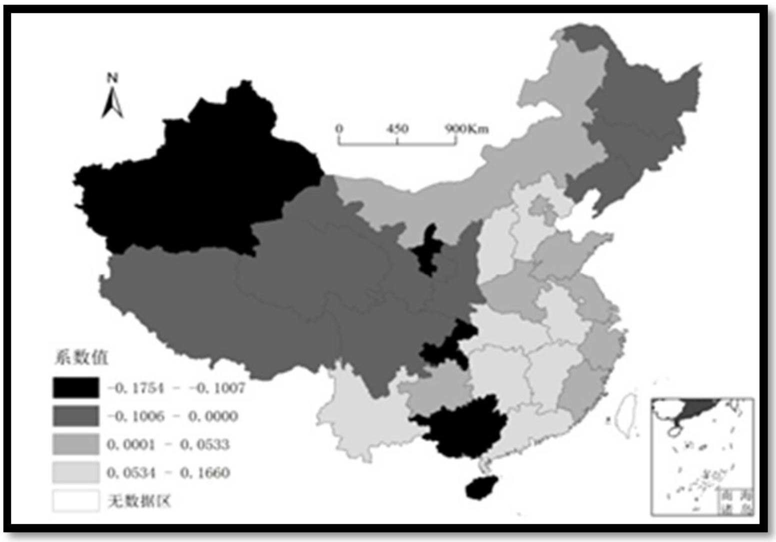

Figure 3: Spatial Distribution of Tax to WATER Coefficient in 2000

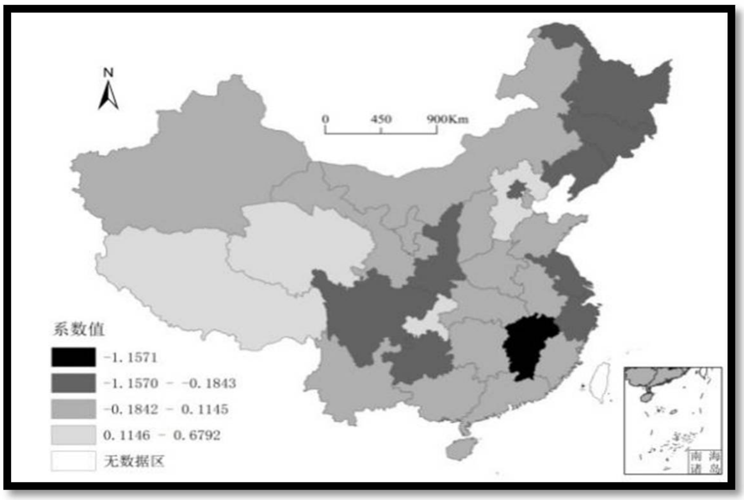

Figure 4: Spatial Distribution of Tax to WATER Coefficient in 2017

Through the analysis of the spatial distribution of the estimated coefficients in the GTWR model, it can be seen that the impact of tax competition (*lnTAX*) on regional environmental pollution (*lnSO2/lnWATER*) has significant spatial differentiation.

- When the pollutant is SO2. According to the quintile regression results of the GTWR model in table 3, from the national perspective, some of the impacts of tax competition (*lnTAX*) on regional SO2 emissions (*lnSO2*) are positive while some are negative, and the estimated coefficient values in the GTWR model are between -9.7216-5.9177. In 2000, the regression coefficients of tax competition on regional SO2 emissions were mostly negative (as shown in figure 1), accounting for 64.52% of the 31 provinces and regions in China, which means that tax competition plays a negative inhibitory effect on SO2 emissions and is conducive to the optimization of environmental quality. In 2017, the regression coefficients of tax competition on regional SO2 emissions were mostly positive (as shown in figure 2), accounting for 74.19% of the 31 provinces and regions in China, which means that tax competition plays a positive effect on SO2 emissions and exacerbates the deterioration of environmental quality.

- When the pollutant is wastewater. According to the quintile regression results of the GTWR model in table 3, from the national perspective, some of the impacts of tax competition (*InTAX*) on regional wastewater discharge (*InWATER*) are positive, while some are negative, and the estimated coefficient values in the GTWR model are between -1.1571-0.6792. In 2000, the regression coefficients of tax competition on the regional wastewater discharge were mostly negative (as shown in figure 3), accounting for 80.65% of the 31 provinces and regions in China, which means that tax competition plays a negative inhibitory effect on the wastewater discharge and is conducive to the optimization of environmental quality.
- In 2017, the regression coefficients of tax competition on regional wastewater discharge were mostly positive (as shown in figure 4), accounting for 58.06% of the 31 provinces and regions in China, which means that tax competition played a positive effect on wastewater discharge and aggravated the deterioration of environmental quality.

3.2. Spatial Correlation Pattern of GTWR Estimated Coefficients Based on LISA

The above-estimated coefficients of the GTWR model reflect the impact of tax competition (*InTAX*) between local governments on regional environmental pollution (*InSO2/InWATER*). In order to further reveal the spatial correlation between the impact of tax competition on the environmental pollution emission level. Then, the paper uses the LISA analysis method commonly used in the exploratory spatial data analysis (ESDA) to measure the spatial correlation pattern of the GTWR estimated coefficients of the impact of tax competition on environmental pollution. Before the LISA analysis, the spatial weight matrix needs to be selected. In the paper, the geospatial weight matrix ($W_{\rm geo}$) is selected. The construction method is: let $W_{\rm geo} = 1/d_{\rm ij}^2,\ i \neq j$, otherwise, it is 0. The geographic weight distance (d_{ij}) is calculated by using the latitude and longitude of the surface distance between provinces. In the process of specific empirical measurement and model estimation, the paper will 'standardize' the geospatial weight matrix to ensure that the sum of the elements in each row of the geospatial weight matrix is equal to 1.

According to the spatial clustering analysis method, the Moran's I index and Moran scatter diagram of the GTWR estimated coefficients of regional environmental pollution (*InSO2/InWATER*). They are affected by tax competition (*InTAX*) in China under the geospatial weight matrix and are calculated to clarify the spatial correlation pattern and spatial heterogeneity characteristics of the estimated coefficients of the impact of tax competition on regional environmental pollution.

Year	Moran's I Index		Year	Moran's I Index	
	InSO2	*InWATER*		*InSO2*	*InWATER*
2000	-0.044	0.044	2009	0.116**	0.078*
2001	-0.011	0.077*	2010	0.063*	0.149**
2002	0.027	0.112**	2011	0.070*	0.111*
2003	0.091*	0.137**	2012	0.030*	0.069*
2004	0.204***	0.130**	2013	0.126**	0.083*
2005	0.268***	0.123**	2014	0.159**	0.104*
2006	0.298***	0.120**	2015	0.156**	0.119**
2007	0.368***	0.071*	2016	0.149**	0.131**
2008	0.254***	0.013*	2017	0.140**	0.139**

Table 4: Moran's I Index of GTWR Estimated Coefficients of Environmental Pollution Affected by Tax Competition
*Note: ***, ** and * Represent Significance Level of 1%, 5% and 10%, Respectively*

According to the analysis of Moran's I index in Table 4, it can be seen that:

(1) When the pollutant is SO2. Except for some years such as 2000, 2001, and 2002, the estimated coefficients of tax competition (*InTAX*) on SO2 emissions (*InSO2*) in most years of the GTWR model are basically positive based on Moran's I index under the geospatial weight matrix, and has passed the significance level test of at least 10%. This indicates that since 2003, the estimated coefficients of tax competition on SO2 emissions have a significant positive autocorrelation in geospatial.

(2) When the pollutant is wastewater. Except for the year 2000, the estimated coefficients of tax competition (*InTAX*) on wastewater discharge (*InWATER*) in other years in the GTWR model are basically positive based on Moran's I index under the geospatial weight matrix and have passed the significance level test of at least 10%. This indicates that since 2001, the estimated coefficients of tax competition on wastewater discharge have had a significant positive autocorrelation in geospatial.

Moran's I index only reflects that there exists significant spatial dependence in the spatial distribution in the estimated coefficients in the GTWR model of tax competition (*lnTAX*) affecting regional environmental pollution (*lnSO2/lnWATER*). However, it cannot distinguish the specific spatial agglomeration pattern. At this time, we can reveal the high-value agglomeration and low-value agglomeration among regions by observing Moran scatter plot. In order to more intuitively describe the spatial agglomeration phenomenon of environmental pollution, the paper further draws the Moran index scatter diagram of GTWR estimated coefficients of tax competition affecting environmental pollution in two typical years, namely 2007 and 2017. Moran scatter plot divides the concentration pattern of GTWR estimated coefficients of tax competition affecting environmental pollution in various regions into four quadrant spatial correlation patterns. The first and the third quadrant show positive spatial correlation, and the second and the fourth quadrant show negative spatial correlation. They are shown in table 5.

Quadrant	Distribution Characteristics of Moran Scatter Plot	The Specific Connotation
The first quadrant	HH: High estimated value - high spatial lag value	Indicates that the provinces with a high coefficient estimated value are surrounded by other provinces with a high coefficient estimated value
The second quadrant	LH: Low estimated value - high spatial lag value	Indicates that the provinces with low coefficient estimated value are surrounded by other provinces with a high coefficient estimated value
The third quadrant	LL: Low estimated value - low spatial lag value	Indicates that the provinces with a low coefficient estimated value are surrounded by other provinces with a low coefficient estimated value
The fourth quadrant	HL: High estimated value - low spatial lag value	Indicates that the provinces with a high coefficient estimated value are surrounded by other provinces with a low coefficient estimated value

Table 5: Distribution of Moran Scatter Plot of GTWR Estimated Coefficients of Tax Competition Affecting Environmental Pollution

Figures 5, 6, 7, and 8 are the Moran scatter plots of the estimated coefficients in the GTWR model of tax competition (*lnTAX*) affecting regional environmental pollution (*lnSO2/lnWATER*) in 2007 and 2017, respectively.

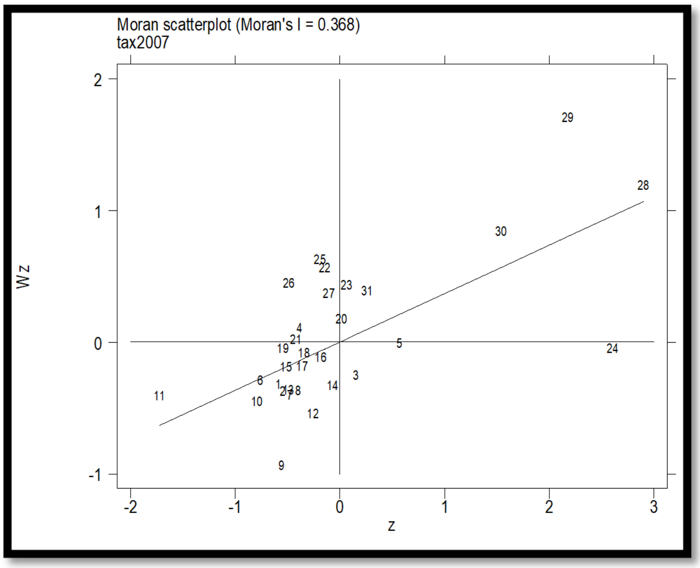

Figure 5: Moran Scatter Plot of Tax to SO2 Coefficients in 2007

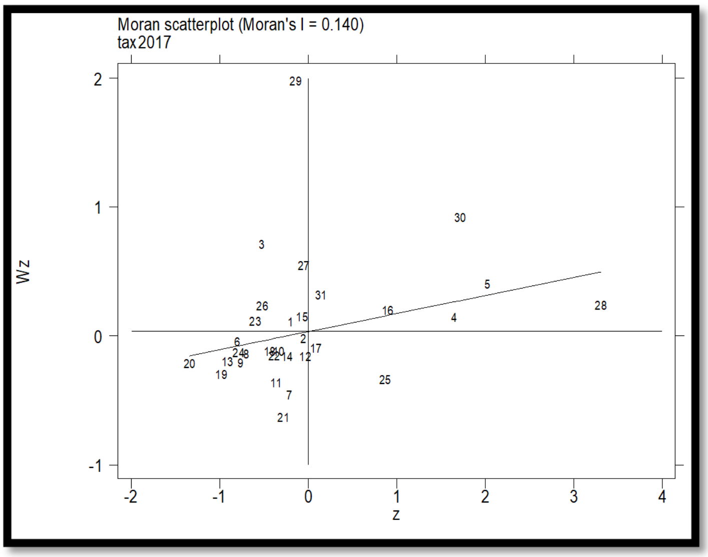

Figure 6: Moran Scatter Plot of Tax to SO2 Coefficients in 2017

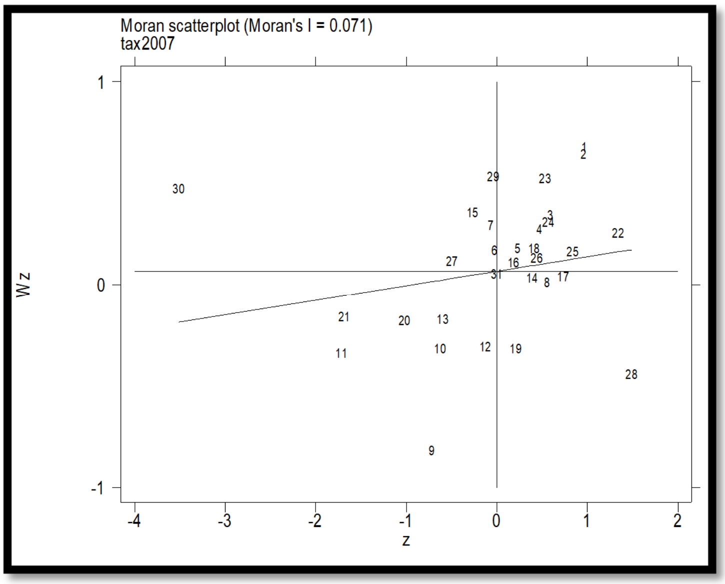

Figure 7: Moran Scatter Plot of Tax to WATER Coefficients in 2007

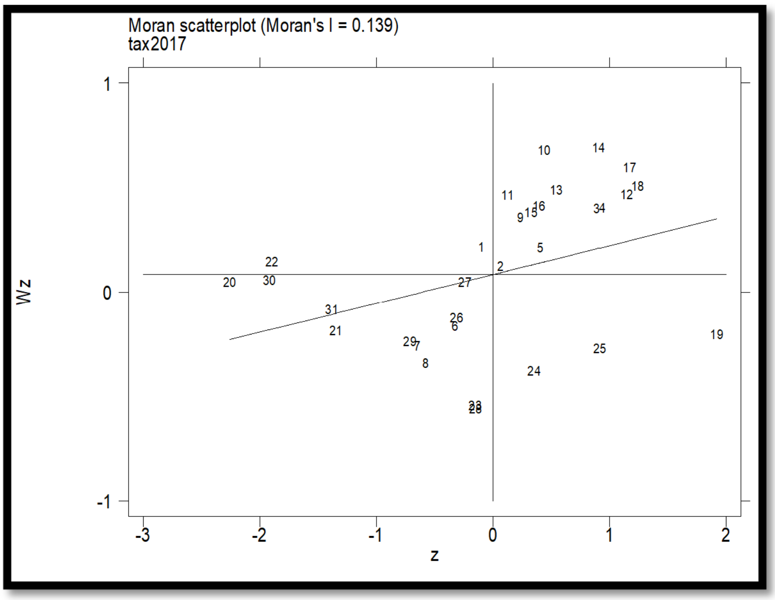

Figure 8: Moran Scatter Plot of Tax to WATER Coefficients in 2017

By analyzing the spatial correlation pattern measurement results of the estimated coefficients of the GTWR model, it can be seen that:

(1) When the pollutant is SO2. The Moran scatter plot corresponding to the GTWR estimated coefficients of the impact of tax competition (*InTAX*) on SO2 emissions (*InSO2*) in 2007 and 2017. It shows that most of the regions are located in the third quadrant (as shown in figure 5 and figure 6). The GTWR estimated coefficients of the provinces in the third quadrant (low-low type) and their neighboring provinces present a significant negative correlation. The estimated coefficients are low, which can be regarded as the 'depression' of the GTWR estimated coefficients, that is, the agglomeration areas where the impact of tax competition on SO2 emissions is relatively low. It indicates that the effect of tax competition on regional SO2 emissions presents a spatial correlation pattern of 'low-low' characteristics, and the 'depression' effect in the regional spatial pattern has initially appeared.

(2) When the pollutant is wastewater. The Moran scatter plot corresponding to the GTWR estimated coefficients of the impact of tax competition (*InTAX*) on wastewater discharge (*InWATER*) in 2007 and 2017, which shows that most of the regions are located in the first quadrant (as shown in figure 7 and figure 8). The GTWR estimated coefficients of the provinces in the first quadrant (high-high type) and their neighboring provinces present a significant positive correlation. The estimated coefficients are all high, which can be regarded as the 'highland' of the GTWR estimated coefficients t, that is, the agglomeration area with a relatively high impact of tax competition on the wastewater discharge shows that the effect of tax competition on the regional wastewater discharge presents a spatial correlation pattern of 'high -high' characteristics, and the 'highland' effect of the impact on the regional spatial pattern has also begun to appear.

In conclusion, the measurement results of the spatial correlation pattern of the estimated coefficients in the GTWR model further confirm that there is a significant spatial positive correlation (spatial dependence) between the impact of tax competition on regional environmental pollution in China. Most provinces and regions show similar spatial cluster characteristics to their neighboring provinces and regions. Provinces and regions with a small impact on SO2 emissions are adjacent to each other in space, and the provinces and regions where tax competition greatly impacts wastewater discharge tend to be concentrated (Ding Gang & Chen Qiling, 2014) [7]. There is a close relationship between tax resources and environmental protection in various provinces and regions, and this relationship is different among provinces and regions. It may not only bring positive spatial externalities to promote economic development and environmental quality optimization in other provinces and regions but also bring a certain degree of negative spatial externalities, which will intensify the strategic competitive emission of spillover pollutants.

4. Main Conclusions and Policy Implications

From the perspective of spatial heterogeneity, based on the panel data of 31 provinces and regions in China covering from 2000 to 2017, this paper uses the GTWR model to investigate the effect of tax competition on regional environmental pollution and the spatial impact difference, and then uses the LISA analysis method to measure the spatial correlation pattern of the estimated coefficients of the GTWR model. The following conclusions and enlightenment are as follows:

Firstly, there are regional and individual differences in economic factors, such as tax competition, which cannot be ignored. The differences lead to significant spatial heterogeneity in the regional distribution of environmental pollution. By introducing the spatial effect to investigate the impact of tax competition on environmental pollution in various provinces and regions, it is not difficult to find that there is a significant spatial difference, and the regional environmental pollution emission level and the influencing factors are not invariable constant. Therefore, different regions should fully use their own resource endowment advantages, spatial location advantages, and policy environment advantages when formulating environmental governance policies to save environmental governance costs. At the same time, while formulating tax preferential policies, we must fully consider the heterogeneous impact of external factors, such as regional resource endowment, economic development foundation, and spatial location conditions, and pay attention to the overall cooperation and coordination between tax policies and other policy means and try our best to avoid the positive spillover effect of factors such as tax competition among local governments on regional environmental quality optimization due to regional economic imbalance.

Secondly, the impact of tax competition on regional environmental pollution presents a significant spatial dependence, and its spatial pattern has initially shown the coexistence of 'highland' effect and 'depression' effect. The effect of tax competition on regional SO2 emission shows a spatial correlation pattern of 'low-low' characteristics. The impact shows a 'depression' effect in the regional spatial pattern, that is, the provinces with less impact are spatially adjacent to each other. The effect of tax competition on regional wastewater discharge shows a spatial correlation pattern of 'high-high' characteristics. The impact shows a 'highland' effect in the regional spatial pattern, that is, the provinces and regions with greater impact are spatially adjacent to each other based on the empirical evidence, such as the differences in the impact of tax competition between local governments on regional environmental pollution emissions and the spatial dependence of its impact. On the one hand, we are required to formulate targeted and oriented tax control policies to guide the flow of resource elements from 'non-green' regions, industries, and departments to 'green' regions, industries, and departments in a reasonable and orderly manner. On the other hand, we can implement classified treatment strategies for different environmental pollutants from the perspectives of spillover degree, treatment cost, emission level, and physical form.

Finally, the governments should formulate and improve the rectification and optimization plan of the tax competition mechanism that is compatible with the goal of high-quality development of a green economy and reverse the 'short-sighted behavior' of local governments that sacrifice environmental quality for tax revenue and economic growth due to the expanding fiscal gap.

(1) Local governments should:

- Promote the view of political achievements of green GDP and the assessment and incentive system of local governments and officials with multiple promotion standards, and
- Reduce the possibility of local governments and enterprises conspiring to discharge pollutants by strengthening the accountability and supervision mechanism of the network media, professional organizations, and the public to local governments.

(2) Local governments should actively build a risk-sharing mechanism, a benefit-sharing mechanism, and a tolerance mechanism integrating 'trial and error tolerance error correction' for cross-regional environmental collaborative governance that can effectively solve the problem of environmental pollution space spillover.

(3) Local governments should focus on building healthy new-type political and commercial relations and realize the transformation of the government governance model from 'regulatory government' and 'all-round government' to 'service regulatory government' to effectively avoid the alienation of environmental policy implementation.

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