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Effect of tourism development on urban air pollution in China: The moderating role of tourism infrastructure

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ABSTRACT

Tourism development has become increasingly important in supporting China's sustained economic growth. However, unreasonable tourism exploitation and large energy consumption have brought severe challenges to China's urban environment, particularly for air pollution problems which constrains improvements in sustainable economic development and social welfare. This paper is aim to empirically investigate the direct and spatial spillover effects of tourism development on air pollution in China using panel data from 285 prefecture-level cities from 2005 to 2017. After spatial correlation statistical analysis, this research employs a generalized nested spatial econometric model (GNS) to conduct empirical estimations. The results demonstrate that the tourism development's direct effect on $PM_{2.5}$ concentrations takes on an inverted U-shaped relationship. In contrast, the indirect effect of tourism development on $PM_{2.5}$ demonstrates reveals a U-shaped relationship. For industrial SO_2 emissions, both the direct and indirect effect of tourism development have inverted U-shape relationships. We find that urban high-speed rail construction and tourism resources play an important moderating role in the relationships between tourism development and urban industrial SO_2 emissions. These results confirm a tourism-environment Kuznets curve in the context of China, with significant spatial spillover effects from tourism development on air pollution. We conducted two robustness tests and then offer policy suggestions to reduce air pollution.

1. Introduction

Tourism development has increasingly become an important force to promote China and even global economic growth. According to the "China Tourism Industry Market Outlook and Investment Strategic Planning Analysis Report 2020–2025", the total number of global tourism people reached 11.88 billion in 2017, 1.6 times the size of the global population; while the global tourism income reached 5.3 trillion US dollars, accounting for 6.7 percent of the global GDP. Tourism has surpassed global economic growth for the seventh consecutive year, becoming the fastest growing industry economy in the world. For China, the positive spillover effect of tourism has greatly stimulated the development of other non-tourism sectors such as China's manufacturing industry, transportation industry, service industry and so on (Zhang and Gao,2016). The total contribution of tourism to China's economy in 2017 is 9.12 trillion yuan, with a contribution rate of about 11%, according to the "2018 Travel and Tourism Global Economic Impact Report". The growth of China's tourism contribution to GDP exceeds that of other countries, ranking first in the world. The comprehensive contribution of China's national tourism industry to GDP in 2018 was 9.94 trillion yuan, accounting for 11.04% of GDP; 28.26 million people were directly employed in tourism, and 79.91 million were directly and indirectly employed in tourism, accounting for 10.29% of the total employment population in China. Thus, as the pace of consumption upgrading accelerates, tourism has become a new driving force for China's consumption, employment and economic growth.

However, the problem of tourism environmental pollution, especially air pollution, has begun to attract wide attention with the improvement of human environmental awareness. Tourism is considered to be an important source of negative environmental externalities (Jones and Munday,2004; Saenz-de-Miera and

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Rossello*,2014). Economic growth and development driven by tourism at the cost of environmental pollution and degradation (Azam et al., 2018), which will ultimately hindering future tourism development and harming human health. Shahbaz et al.(2015) believe that countries that are over pursuing tourism development goals will pay additional costs for their environmental consequences and climate change. Numerous empirical studies have shown that tourism development will results severe externalities challenges to the environment, although it is important for employment and growth (Saenz-de-Miera and Rossello.,2014; Azam et al., 2018), and that the externalities of tourism on the environment are not simply linear (Paramati et al., 2017; Sherafatian-Jahromi et al., 2017; Zhang and Gao.,2016). In recent years, China's tourism industry has made rapid development and become an important pole of China's economic growth, but this is not enough to make us ignore its possible damage to the environment. Regrettably, although the Chinese government regards energy saving and emission reduction and environmental protection as one of the most important tasks of social and economic development (Zhou et al., 2015), the environmental externality of tourism development in China has not been widely discussed in academically.

Tourism infrastructure, usually includes the traffic, accommodation and attractions (Virkar and Mallya,2018), plays an important role in the relationship between tourism development and environmental pollution (Kanwal et al., 2020). Among them, the traffic infrastructure construction is crucial in attracting tourists and enhancing existing tourism activities, which can not only facilitate the flow of tourists between regions, but also help to promote the development of destination tourist attractions (Virkar and Mallya, 2018). Prior empirical studies have demonstrated that a well-developed traffic infrastructure can reduces the time cost of tourists (Kanwal et al., 2019) and greatly increases passenger flow in tourism (Kanwal et al., 2019; Nazneen et al., 2019). Moreover, tourism is resource-oriented and tourism resources are vital for tourism development (MELIAN-GONZALEZ and GARCIA-FALCON, 2003), especially for tourist attractions, as an important basis of tourism economic development (Yang, 2015), their are deeply affect the choice of tourist destinations. But this is a double-edged sword, blind development and expansion of some tourist attractions often results environmental pollution. Higham et al.(2016) believe that the demand for transportation, catering, accommodation and other facilities and services generated by tourist mobility is an important factor leading to global air pollution emissions. Therefore, the role of tourism infrastructure in the relationship between tourism development and environmental pollution needs to be further explored.

Tourism air pollution has seriously affect the quality of life and social welfare of urban residents in China (Hao and Liu,2016). In existing researches, although the environmental externalities of tourism development has been extensively discussed, however, the prior studies generally focus on the effect of tourism development on specifically air pollutants CO_2 (Azam et al., 2018; Paramati et al., 2017; Sherafatian-Jahromi et al., 2017; Zhang and Gao. 2016), only a few studies concern the other pollution indicators, such as PM_{10} (Saenz-de-Miera and Rosselló. 2014), and these researches rarely involve the spatial spillover and non-linear effects of tourism environmental externalities. Moreover, transportation and tourism resources are important aspects of tourism economic development. But so far, no studies focused on the moderating effects of these two tourism infrastructures on tourism environmental externalities. In addition, China's special institutional background also determines that a specific analysis of China is necessary. To this end, the purpose of this paper is originally to explore the air pollution effect of tourism development in Chinese context use the specific air pollutants $PM_{2.5}$ and SO_2 to make up for the current research gaps. The main innovations of the paper are reflected in the following aspects: Firstly, the direct and spillover effects of tourism development on urban air pollution were tested using specific air pollutants $PM_{2.5}$ and SO_2. This work is a complement for the prior studies using the comprehensive index of air pollution that is difficult to accurately identify the contribution of a specific index (Zeng et al., 2019); Secondly, we also found the relationship between tourism development and urban air pollution are presented an inverted U-shape, that is, the tourism environment Kuznets curve is valid in the Chinese context. This conclusion is weakly supported in the study of CO_2 as a proxy variable of air pollution(Zhang, 2018); Finally, we innovatively introduced the moderators (tourism infrastructure) to examine the moderating effects of tourism infrastructure on tourism development and urban air pollution, and found that tourism infrastructure is an important moderating mechanism.

This paper is structured as follows: Section 2 is literature review and hypothesis. Section 3 describes the data selection and empirical methodology. Section 4 examines spatial correlation of air pollution and discusses empirical results. Section 5 provides an analysis of the moderating effect. Section 6 presents the conclusions and policy implications.

2. Literature review and hypothesis

2.1. Non-linear effects of tourism development on air pollution

The importance of tourism development for employment and growth has been extensively discussed in existing studies (Zhang and Gao, 2016; Ohlan and Ramphul,2017; Habibi et al., 2018; Dogru and Bulut,2018). However, excessively energy consumption and resource exploitation in tourism sectors prompted scholars to explore tourism environmental externalities (Zhang and Gao, 2016; Azam et al., 2018), especially for tourism air pollution, which is closely related to people's daily life (Saenz-de-Miera and Rossello., 2014; Paramati et al., 2017; Sherafatian-Jahromi et al., 2017). For this reason, we aim to study the air pollution effects of tourism development based on specific air pollutants $PM_{2.5}$ and SO_2 in this paper.

The impact of tourism development on air pollution can be summarized as follows: Firstly, tourism development involves resource exploitation and energy consumption. Generally, tourism development is a process of artificial changes of the ecological environment, which often leads to buildings destruction and biodiversity and ecosystem damage (Sáenz de-Miera and Rosselló, 2013), over-exploitation of resources (Jones,2004), especially in tourism oriented economies. Moreover, the problem of energy consumption resulting from the increased demand for transportation, accommodation, catering and other related services from tourism development is more obvious. Among them, transportation is one of the core factor of tourism development, accompanied by the expansion of tourism economy is the rapid expansion of transport demand, which needs to consume more fossil fuels, resulting in emissions of polluting gases. In economies where transport infrastructure is underdeveloped and transport power is largely dependent on the consumption of traditional fossil energy, the environmental pressures from tourists flow are more pronounced.

Secondly, tourism development causes air pollution is obviously proved in prior researches, but this effect is not simply liner (Zhang and Gao.,2016; Paramati et al., 2017; Sherafatian-Jahromi et al., 2017). Although there are some problems in the early stage of tourism industry development, such as over-exploitation, serious waste of resources, poor government governance ability and people lack of awareness of environmental protection. However, in the long run, with the overall strength of the economy and the improvement of people's living conditions, promoting the development of green tourism economy inevitably puts forward higher requirements for the quality of tourism environment. With the strict environmental regulation of the government and the increasing environmental participation of the public, tourism development will cross the inflection point of pollution and become an environmentally friendly industrial sector. In other words, there is an inverted U-shape curve correlation between tourism development and air pollution, that is, the Kuznets curve of tourism environment. This conclusion has been partially validated in existing studies used the specific air pollutants CO_2. For example, Zhang and Gao.(2016) observed that the tourism-induced environmental Kuznets curve hypothesis received weak support in eastern and western China. Paramati et al.(2017) found that the effect of tourism development on CO_2 emissions are falling significantly in developed countries, compared to developing economies, which indicating that tourism growth and environmental Kuznets curve assumptions is valid. Sherafatian-Jahromi et al.(2017) found that tourism environmental Kuznets curves exist in Southeast Asia. Although only a few of the above studies have discussed the nonlinear effects of tourism development on air pollution limited to specific air pollutants CO_2, but it provides useful inspiration for our research. Hence, based on the above analysis, we assume that the effects of tourism development on urban air pollutants $PM_{2.5}$ and SO_2 also exhibit nonlinear characteristics in the context of China. Therefore, we hypothesized that:

H1. There is a positive relationship between tourism development and air pollution in the early stage, while with the development of tourism, this effect will cross the "turning point" and presents negative, that is, there is an inverted U-shape between tourism development and air pollution.

2.2. Moderating effect of tourism infrastructure

Tourism infrastructure (traffic construction and tourist attractions, etc.) is an important part to promote the development of tourism industry (Virkar and Mallya, 2018; Kanwal et al., 2020). Transportation, including air, water and land, is one of the core elements of tourism development, which provides transportation services for tourists from source to destination. However, currently in China, all modes of transportation are still powered by huge fossil fuel consumption, a process that produces large particulate matter (PM) and greenhouse gas (CO_2) emissions (Yeoman et al., 2007; Mayor and Tol, 2010; Liu et al., 2011; MacNeill and Wozniak, 2018). For example, the automobile is the first choice vehicle for tourists to flow in short distance because of its flexibility and convenience. Studies have shown that automobiles are one of the important sources of urban air pollution, especially in low-speed vehicles, which produce more particulate matter and bring more serious urban air pollution (Liu et al., 2011). Therefore, it is urgent to improve the construction of transportation infrastructure to promote the development of green tourism economy. China's high-speed railway construction has made rapid development in recent years. The high-speed railway, as a sustainable green mode of transportation, increases the travel mode available to tourists and reduces the use of private cars to a large extent, and then reduces traffic congestion and vehicle exhaust emissions (Dong and Zhu, 2016; Zhu et al., 2019). on the other hand, it promotes regional opening and factor circulation by improving traffic conditions (Wang and Ni.,2016), realizes economies scale effect, technological innovation and industrial upgrading, objectively contributes to regional environmental optimization (Zhu et al., 2019). Therefore, we believe that the high-speed railway, as an alternative mode of transportation for tourists, not only provides convenience for tourists to flow across regions, but also helps to realize the scale effect of tourism production factors, and then improves the tourism environment in China.

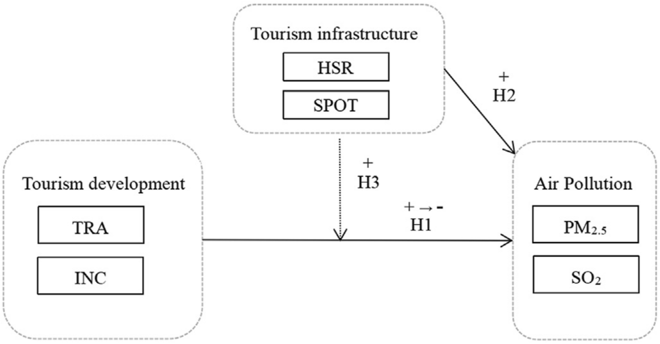

Fig. 1. Research framework. Abbreviations: TRA: total number of tourists; INC: tourism income; HSR: high speed railway; SPOT: 5A-secnic spots. Note: Solid line represent the direct relationships, dotted line represent the moderate relationships.

The tourist attractions is another core element related to the development of tourism industry. Tourism is a resource-oriented industrial sector, and tourism resources are the basis of tourism development (MELIAN-GONZALEZ and GARCIA-FALCON,2003). However, the endowment of tourism resources in various cities in China must be very different due to the long history culture and vast land area. After China's reform and opening up, the central and local governments at all levels gradually began to attach importance to the role of tourism economy in regional development, and to exploit tourism resources in various regions. Therefore, the government has carried out a variety of promotion marketing and tourism brand shaping activities for tourism resources, among which the rating of tourist attractions in 2003 is an important measure.[1] 5A scenic spots means rich tourist resources and better tourist environment, and the development of related tourism industry is mainly based on the existing natural or human landscape for small scale exploitation, so the development is environmentally friendly. Based on the above analysis, we believe that tourism infrastructure plays an important role in the relationship between tourism development and air pollution. Here, we hypothesized that:

H2. There is a positive relationship between tourism infrastructure (HSR and SPOT) and air pollution. That is, tourism infrastructure development can reduce air pollution.

H3. Tourism infrastructure mediate the relationship between tourism development and air pollution.

Fig. 1 shows the research framework of the paper. We can intuitively see that, the impacts of tourism development on air pollution transform from positive to negative statistically. Tourism infrastructure not only has a positive impact on air pollution, but also positively moderating the relationship between tourism development and air pollution in statistics.

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[1] Grade A quality assessment is a unique scenic area management method in China. The rating of tourist scenic spots affects the judgment of tourists on the quality of scenic spots; environment and sanitation are the important basis for the quality assessment of A-level tourist scenic spots; according to the Classification and Assessment of the Quality Grades of Scenic Spots, the quality level of China's tourist scenic spots is divided into five, from high to low, AAAAA, AAAA, AAA, AA, and A-level.

3. Data and methodology

3.1. Data selection and variable description

This paper used the panel data of 285 prefecture-level cities (includes Beijing, Tianjin, Shanghai, and Chongqing) in China from 2005 to 2017. According to the latest version of the Ambient Air Quality Standard (GB3095-2012) in China, ambient air pollutants generally includes six items, which are SO_2, NO_2, CO, O_3, $PM_{2.5}$ and PM_{10}. Subdivided air pollution indicators such as BC, CO, NH_3, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and HC have been widely discussed in existing studies (Liang and Xi, 2016; Li et al., 2018). Considering the result of existing researches shows that $PM_{2.5}$ concentrations and SO_2 emissions are the culprits of air pollution in Chinese cities (Costa et al., 2017; Wang et al., 2014; Li et al., 2018 ; ; Zeng et al., 2019; Chen et al., 2020; Qu et al., 2020), and limited to the availability and completeness of panel data, the most major air pollution indicators $PM_{2.5}$ concentrations and SO_2 emissions are defined as dependent variables in this paper. The data of $PM_{2.5}$ and SO_2 emissions can be obtained from the official website of the National Bureau of Statistics of China and the China City Statistical Yearbook respectively.

Tourism development is the core independent variable in our research. Tourism development refers to the development of urban tourism industry, which is measured by the number of urban annual tourist arrivals (TRA) and tourism income (INC) that commonly used in existing research (Saenz-de-Miera and Rossello,2014; Azam et al., 2018). In the context of the development of global tourism economy, the number of tourists and tourism income are increasingly considered to be an important indicator of the economic status of a region. Therefore, attracting tourists and increasing tourism revenue has become one of the goals pursued by policy makers in regional governments. The data of total number of tourists (TRA) and tourism income (INC) in cities can be obtained from the National Bureau of Statistics of China and the Yearbook of China Tourism Statistics.

Tourism infrastructure is regarded as moderating variable in this paper, includes High-speed rail (HSR) and tourist attractions (SPOT), which is measured by high-speed rail mileage and the number of 5A-level scenic spots respectively. The environmental quality of cities with a large number of 5A-level tourist attractions is relatively high. The high-speed rail mileage data in the same period of each city were collected by the author from network.[2] The number of 5A-level scenic spots were gathered from the network and city's official website.

Furthermore, based on the existing researches, the level of urbanization (URB)(Li et al., 2018), economic development level (PGDP)(Ding et al., 2019), the number of population(POP)(Lu and Feng, 2014), transport infrastructure (ROAD), and industrial structure (ACC) have significant effect on the city's air pollution (Lin et al., 2009; Sarzynski, 2012; Wang and Huang, 2015; Sun et al., 2018), so these variables were also be controlled in our model. The control variables data were obtained from the China City Statistical Yearbook. Descriptive statistic of the main variables are presented in Table 1.

3.2. The generalized nested spatial econometric model

According to the previous analysis, tourism development has an important impact on urban air pollution, and this impact may not be linear. Generally, it would inevitably cause environmental damaged and energy consumption because of excessive exploitation, disorderly planning, weak environmental awareness, and low governance capacity in the early stage of urban tourism development. But in the long run, a high-quality environment is necessary to promote the in-depth development of the tourism economy with the improvement of the overall strength of China's economy and the improvement of people's living conditions. Therefore, we speculated that there is an inverted U-shaped relationship between tourism development and urban air pollution in China.

In addition, the development of a city's tourism industry is not limited to within the administrative jurisdiction, but there are so many cross-regional industrial exchanges and factor flows. It's an effective channel to generate spatial spillover effects from tourism development in this process. There is also a significant spatial correlation between air pollution in neighboring cities (Hao and Liu, 2016; Liu et al., 2017; Ma et al., 2016; Zhang et al., 2018). Due to the spatial dependence, both the observable and unobservable variables in a region can affect the surrounding areas through the effects of air pollution spillovers between regions (Liu et al., 2017). Therefore, this paper comprehensively considers the spatial spillover effects of air pollution, tourism development, and unobservable variables, and sets up a generalized nested spatial econometric model (GNS).

$$\begin{aligned} airpollution_{it} &= a_o + \rho\sum_{j=1}^{N} w_{ij}airpollution_{jt} \\ &+\beta X_{it} + \lambda\sum_{j=1}^{N} w_{ij}X_{jt} + \mu_i + \varepsilon_{it} \\ \varepsilon_{it} &= \gamma\sum_{j=1}^{N} w_{ij}\varepsilon_{jt} + \nu_{it} \end{aligned} \tag{1}$$

Where subscript i, j and t represents the cities, neighboring cities and time periods respectively. In Equation (1), airpollution (including $PM_{2.5}$ and SO_2) is the dependent variable, ρ reflects the spatial dependence of airpollution; w_{ij} is the spatial weight matrix where i and j refers to the element at row i and column j; X is a vector of independent variables, includes the core indenpendent variables logarithm of tourists (TRA), logarithm of tourism income (INC) and the square of them $(TRA)^2$ (INC),^{2} and the control variables logarithm of urban population (POP), logarithm of per capita GDP (PGDP), and it's quadratic term (PGDP),^{2} transport infrastructure (ROAD), urbanization (URB), and the number of employees in accommodation and catering (ACC). $\beta$is the regression coefficient of independent variables, λreflects the spatial dependence of these independent variables. $\mu_i$represents cities heterogeneity, which is the unobserved random variable. $\varepsilon_{it}$is error term, γdonates the spatial dependence of error term.

It is worth noting that we added the interaction term of the moderating variables and the core independents (lntravel×moderator and lntravel^2×moderator) in Equation (1) directly when examining the moderating effects of tourism infrastructure. The moderator refers to tourism infrastructure, includes high-speed rail (HSR) and 5-A scenic spots (SPOT). The rest the same as in equation (1).

4. Result and discussion

We selected the appropriate spatial weight matrix, tested the spatial autocorrelation of $PM_{2.5}$ concentration and industrial SO_2 emissions by Moran's I, used the generalized nested spatial econometric model to investigate the spatial spillover effects of tourism development on air pollution, and performed two robustness tests in this section.

4.1. Spatial weight matrix

Selecting an appropriate method to measure the spatial distance

Table 1
Descriptive statistics for variables.

Variables	Definition	Obs	Mean	SD	Min	Max
Dependent variables						
$PM_{2.5}$	Annual $PM_{2.5}$ concentrations from 2005 to 2017 in China's 285 cities	3705	37.722	16.596	4.68	90.86
SO_2	Annual industrial sulphur dioxide emissions from 2005 to 2017 in China's 285 cities (10,000 tons)	3705	5.616	5.681	0	68.316
Independent variables						
TRA	Logarithm of annual number of tourists	3705	7.121	1.199	1.651	10.9
INC	Logarithm of annual tourism income from cities	3705	4.503	1.441	−1.897	8.541
Moderating variables						
HSR	Miles of high-speed rail (km)	3705	421.966	480.634	0	1759
SPOT	Number of national 5A scenic spots (n)	3705	0.379	0.799	0	8
Control variables						
URB	Proportion of urban population (%)	3705	0.327	0.197	0.038	0.987
POP	Year-end population in cities	3705	5.852	0.702	2.846	8.91
PGDP	Per capita GDP	3705	10.244	0.842	3.892	13.056
ROAD	Number of passengers on road transport (10,000)	3705	8372.062	14359.18	0.68	286557
ACC	Number of employees in accommodation and catering (10,000)	3705	0.977	3.712	0.01	78.03

Notes; TRA, INC, POP and PGDP in the table are expressed in their natural logarithmic forms.

between regions is critical to spatial analysis. Referring to existing research (Ding et al., 2019; Zeng et al., 2019), we defined the spatial weight matrix W_{ij} as whether two cities are neighboring, specifically, their spatial distance was defined as 1 when city *i* and city *j* have a common administrative jurisdictional boundary. When city *i* did not share a common administrative jurisdictional boundary with city *j*, the spatial distance of them was defined as 0. Matrix definition as Equation (2).

$$w_{ij} = \begin{cases} 1, city\ \ i\ \cap\ city\ \ j \neq \varnothing \\ 0, city\ \ i\ \cap\ city\ \ j = \varnothing \end{cases} \tag{2}$$

4.2. Spatial correlation of air pollution in China

We conducted a set of Moran's I test on urban air pollution indicators $PM_{2.5}$ and SO_2 to measure the spatial autocorrelation of urban air pollution in China. The Moran's I index is considered to be an important indicator to measure spatial correlation, which can describe the spatial distribution of autocorrelation variables clearly (Wang et al., 2018). Hence, in this paper, we calculated the global Moran's I value of $PM_{2.5}$ and SO_2 from 2005 to 2017 using Stata15.0 software. The results are shown in Table 2. As we can see from Table 2, Moran's I values of $PM_{2.5}$ concentrations and SO_2 emissions are significant and positive at 1% level among all years. This result indicates that there is a spatial dependence of $PM_{2.5}$ concentrations and SO_2 emissions among cities in China, meanwhile, the spatial dependence of them has higher stability. The spatial autocorrelation result of $PM_{2.5}$ is in line with existed study (Ding et al., 2019).

Table 2
Global Moran's I statistics for PM2.5 and SO2.

Year	$PM_{2.5}$	SO_2
2005	0.663***(28.447)	0.136***(6.223)
2006	0.671***(28.838)	0.128***(5.865)
2007	0.719***(30.840)	0.113***(5.229)
2008	0.663***(28.430)	0.112***(5.192)
2009	0.645***(27.712)	0.114***(5.326)
2010	0.704***(30.190)	0.098***(4.571)
2011	0.702***(30.128)	0.135***(6.083)
2012	0.682***(29.260)	0.169***(7.617)
2013	0.702***(30.157)	0.180***(8.118)
2014	0.652***(27.992)	0.180***(8.146)
2015	0.722***(30.965)	0.162***(7.389)
2016	0.742***(31.856)	0.185***8.173)
2017	0.580***(24.926)	0.176***(7.787)

Note: z-statistics are reported in parenthesis, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Therefore, it also suggests that spatial econometric model estimation is more appropriate in this paper.

Further, we has drawn the spatial distribution map and Moran scatter plot of $PM_{2.5}$ concentrations and SO_2 emissions in 2017 (due to limited space) for the purpose of describing intuitively the spatial correlation of urban air pollution in China (shown in Figs. 2–3). Fig. 2 shows the spatial distribution of $PM_{2.5}$ concentrations and SO_2 emissions in 2017. As shown in the figures, the darker the color, suggests the $PM_{2.5}$ concentrations or SO_2 emissions more serious. We can see that, $PM_{2.5}$ concentrations and SO_2 emissions has a significant spatial autocorrelation, in other words, polluted cities are gather in the same area, e.g. the distribution of $PM_{2.5}$ concentrations in North China Plain. For SO_2 emissions, the cities with the most serious are located in Chongqing, Qujing, Zibo, Xuzhou, and their surrounding cities. Relatively, the cities with less SO_2 emissions are located in Sanya and Haikou in southern China. Fig. 3 shows Moran scatter plot of $PM_{2.5}$ concentrations and SO_2 emissions in 2017. As shown in Fig. 3, the horizontal axis represents $PM_{2.5}$ (SO_2) concentrations, while the vertical axis represents spatial lagged, dots represents a series of cities in our sample. From Fig. 3 we can know that, most dots are distributed in the I and III quadrants, which indicates cities with bad air quality are surrounded by bad ones (or cities with better air quality surrounded by better ones). Overall, we can intuitively draw the conclusion that $PM_{2.5}$ concentrations and SO_2 emissions have significant spatial correlation among cities, and this is consistent with the actual distribution of air pollution in China.

4.3. Empirical results

Table 3, reports the regression results of the GNS model and the panel fixed effect model. But these regression results cannot accurately disclose the marginal effect of tourism development on urban air pollution. It is pointed out that the marginal effect of explanatory variable changes in spatial econometric models should be explained by partial differential methods (Arnold, 2011). According to this idea, this paper further decomposes the direct, indirect,and total effects of the GNS model. The results are shown in Table 4.

4.4. The direct, indirect and total effects on $PM_{2.5}$ and SO_2

Table 4 Panel-A and Panel-B show the direct and indirect effects of the total number of tourists (TRA) and tourism income (INC), respectively.

With respect to the core independent variables. The direct

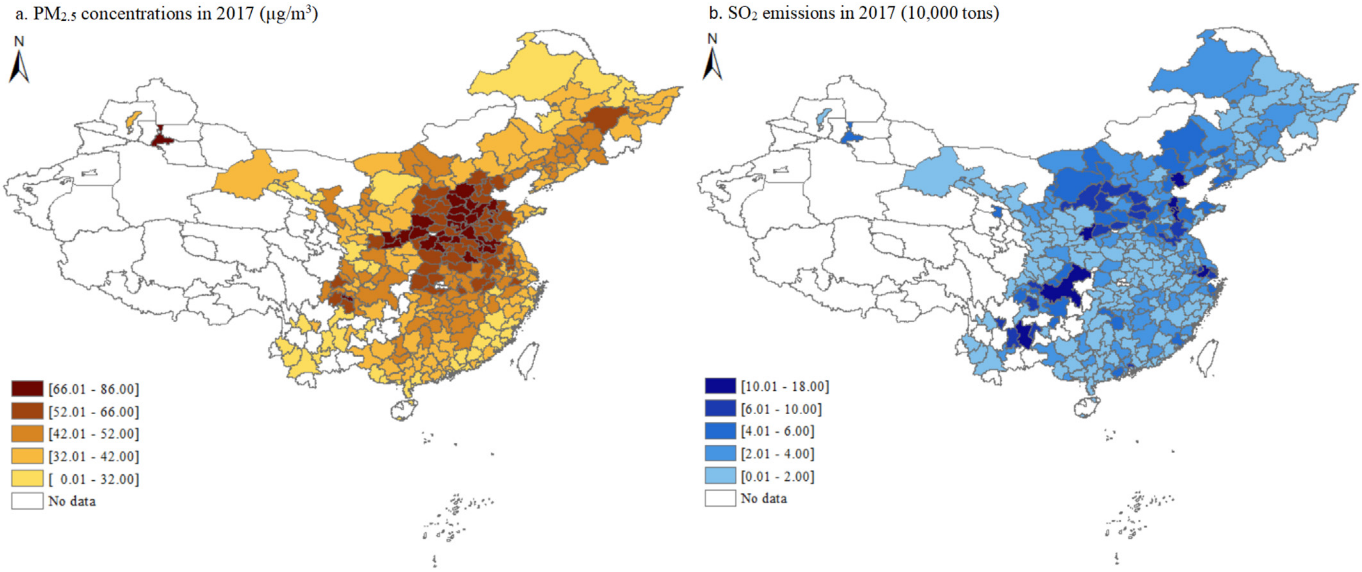

Fig. 2. Spatial distribution of PM2.5 concentrations and SO2 emissions in 2017.

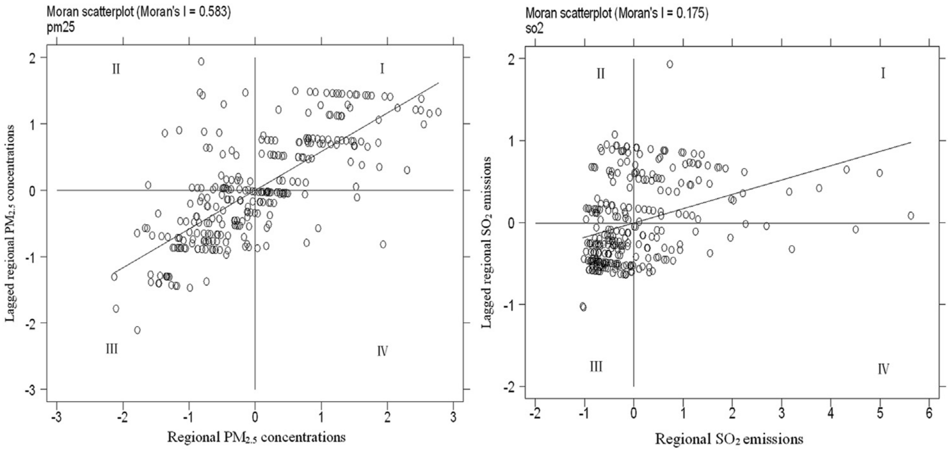

Fig. 3. Moran scatter plot of PM2.5 concentrations and SO2 emissions in 2017.

effects of TRA and (TRA)[2] on $PM_{2.5}$ is significant and the coefficient of them is positive and negative, respectively. This implies that there is an inverted U-shaped relationship between TRA and $PM_{2.5}$; $PM_{2.5}$ first increase with TRA at an increasing rate to reach a maximum. Subsequently, $PM_{2.5}$ decreases at a decreasing rate as TRA continues to rise. We can obtain the maximum when the TRA is equal to 5.952 (i.e., number of tourists is about 3.845 million), which indicates that the rise of TRA can improve air quality when the TRA cross the "turning point" of the inverted U-shaped curve. On average, currently the TRA has crossed the "turning point" of the inverted U-shaped curve, meaning that an increase in the average number of tourists helps to reduce cities' $PM_{2.5}$ emissions in China. However, the indirect effects of TRA on $PM_{2.5}$ is not significant statistically. With respect to INC, we can see that the direct effects of INC on $PM_{2.5}$ is not significant statistically, while the indirect effects of INC on $PM_{2.5}$ is significant and the coefficient of them is negative and positive, respectively. Implying that there is an U-shaped relationship between INC and neighboring cities $PM_{2.5}$; $PM_{2.5}$ first decreases with INC at an decreasing rate to reach a minimum, subsequently, $PM_{2.5}$ increases at an increasing rate as INC continues to rise. We can obtain the minimum when the INC equal to 6.536 (i.e., tourism income is about 6.895 ten billion yuan), which indicates that the rise of INC will deteriorating neighbor cities' air quality when the INC cross the "turning point" of the U-shaped curve, resulting in increased neighboring regions' $PM_{2.5}$ emissions.

Above-mentioned empirical results show that there is an inverted U-shaped relationship between TRA and local $PM_{2.5}$ concentrations while an U-shaped relationship exists in TRA and neighboring cities $PM_{2.5}$ concentrations. The possible reason is, in the early stage of urban tourism industry development, there are many short-sighted behaviors, such as over-exploitation and disorderly competition, and environmental regulations fail to make timely adjustments to meet the rapid development of tourism. Together these factors result in a large amount of $PM_{2.5}$ emission from the cities' tourism industry. With the development of the urban economic, environmental governance capacity and public environmental quality requirements are raised, $PM_{2.5}$ emissions will gradually decrease. At the same time, this also encourages cities to transfer pollutants to neighboring cities, resulting in a positive spatial spillover effect of $PM_{2.5}$ in the neighboring cities.

Further, as shown in SO_2 model, the direct and indirect effects of

Table 3
Regression results of GNS and OLS model.

	GNS				OLS			
	PM$_{2.5}$	SO$_2$	PM$_{2.5}$	SO$_2$	PM$_{2.5}$	SO$_2$	PM$_{2.5}$	SO$_2$
TRA	1.828***(0.700)	2.454***(0.326)			2.270***(0.761)	2.255***(0.703)		
(TRA)^2	−0.176***(0.057)	−0.193***(0.027)			−0.224***(0.066)	−0.165***(0.058)		
INC			0.644*(0.343)	1.087***(0.161)			0.920**(0.400)	1.064***(0.335)
(INC)^2			−0.061(0.041)	−0.159***(0.019)			−0.101**(0.050)	−0.139***(0.038)
URB	−1.043(1.064)	−0.673(0.500)	−0.990(1.066)	−0.564(0.499)	−1.283(0.842)	−0.277(0.571)	−1.126(0.833)	−0.194(0.572)
POP	−2.936***(0.796)	−0.582(0.371)	−2.696***(0.797)	−0.575(0.370)	−2.703*(1.497)	−0.509(0.517)	−2.544*(1.457)	−0.435(0.500)
PGDP	3.635***(1.340)	0.727(0.614)	3.822***(1.347)	0.267(0.619)	3.241**(1.320)	0.562(1.025)	3.225**(1.326)	0.240(1.006)
(PGDP)^2	−0.296***(0.089)	−0.051(0.041)	−0.307***(0.090)	−0.023(0.041)	−0.275***(0.090)	−0.042(0.068)	−0.279***(0.090)	−0.020(0.066)
ROAD	0.012(0.097)	0.070*(0.042)	−0.001(0.097)	0.068(0.042)	−0.036(0.123)	0.0419(0.061)	−0.051(0.125)	0.041(0.060)
ACC	−0.085**(0.037)	−0.248***(0.018)	−0.100***(0.037)	−0.250***(0.018)	−0.088*(0.048)	−0.253**(0.110)	−0.099**(0.043)	−0.255**(0.112)
Cons	4.940***(0.067)	2.366***(0.033)	4.951***(0.068)	2.361***(0.033)	41.928***(10.238)	1.265(4.799)	44.985***(9.688)	7.541*(4.321)
W*TRA	−1.706(1.351)	0.409(0.848)						
W*(TRA)^2	0.262***(0.097)	−0.139**(0.066)						
W*INC			−2.082**(0.831)	0.072(0.487)				
W*(INC)^2			0.292***(0.082)	−0.130**(0.052)				
W*URB	4.197*(2.479)	−2.525*(1.506)	3.221(2.526)	−2.099(1.520)				
W*POP	3.800**(1.730)	−0.722(1.034)	4.158**(1.735)	−1.303(1.032)				
W*PGDP	−0.246(1.904)	−2.575**(1.039)	−0.086(2.064)	−3.528***(1.169)				
W*(PGDP)^2	0.030(0.122)	0.200***(0.067)	0.068(0.133)	0.237***(0.076)				
W*ROAD	−0.344**(0.137)	0.089(0.068)	−0.334**(0.137)	0.094(0.067)				
W*ACC	−0.072(0.102)	0.148**(0.063)	−0.087(0.103)	0.148**(0.063)				
ρ	0.712***(0.017)		0.708***(0.018)					
λ	−0.632***(0.055)		−0.618***(0.058)					
ρ		0.361***(0.082)		0.344***(0.082)				
λ		−0.219(0.137)		−0.214(0.134)				
Wald	2696.03	248.06	2571.9	223.85				
Log-lik/Year	−10545.2	−7834.4	−10546.8	−7824.9	Control	Control	Control	Control
Obs.	3705	3705	3705	3705	3705	3705	3705	3705
Pseudo R^2	0.0520	0.0003	0.0320	0.0003	0.266	0.315	0.264	0.317

Note: Standard errors are in parenthesis, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4
The direct, indirect and total effects of GNS.

	PM$_{2.5}$			SO$_2$		
	Direct effects	**Indirect effects**	**Total effects**	**Direct effects**	**Indirect effects**	**Total effects**
Panel-A number of tourists(TRA)						
TRA	1.738**(2.320)	−1.313(-0.320)	0.424(0.100)	2.525***(7.750)	1.953*(1.660)	4.477***(3.590)
(TRA)^2	−0.146**(-2.480)	0.443(1.610)	0.297(0.470)	−0.204***(-7.820)	−0.314***(-3.890)	−0.518***(-6.160)
URB	−0.274(-0.220)	11.232(1.440)	10.958(1.290)	−0.824(-1.630)	−4.177*(-1.870)	−5.001**(-2.080)
POP	−2.556***(-2.820)	5.559(1.020)	3.003(1.290)	−0.632*(-1.660)	−1.406(-0.890)	−2.038(-1.190)
PGDP	4.156***(3.130)	7.617*(1.560)	11.773**(2.280)	0.602(1.000)	−3.491**(-2.230)	−2.889**(-1.970)
(PGDP)^2	−0.336***(-3.84)	−0.587**(-1.970)	−0.923***(-2.940)	−0.041(-1.010)	0.275***(3.060)	0.234***(2.620)
ROAD	−0.063(-0.097)	−1.092***(-0.349)	−1.154***(-0.372)	0.076*(0.041)	0.173**(0.095)	0.249***(0.103)
ACC	−0.115***(-2.600)	−0.432(-1.340)	−0.547(-1.570)	−0.245***(-13.560)	0.088(0.920)	−0.157(-1.550)
Panel-B tourism income(INC)						
INC	0.289(0.740)	−5.209**(-2.040)	−4.920**(-2.040)	1.109***(6.820)	0.660(0.900)	1.767**(2.280)
(INC)^2	−0.007(-0.160)	0.797***(3.350)	0.790***(3.090)	−0.168***(-8.950)	−0.273***(-3.970)	−0.441***(-6.130)
URB	−0.441(-0.360)	8.071(1.020)	7.629(0.890)	−0.680(-1.340)	−3.380(-1.530)	−4.060*(-1.710)
POP	−2.206**(-2.440)	7.204(1.330)	4.997(0.850)	−0.651*(-1.720)	−2.212(-1.440)	−2.863*(-1.720)
PGDP	4.392***(3.240)	8.381(1.520)	12.773**(2.170)	0.093(0.290)	−5.065***(3.200)	−4.972***(-3.040)
(PGDP)^2	−0.340***(-3.790)	−0.478(-1.370)	−0.817**(-2.210)	−0.012(-0.290)	0.338***(3.340)	0.326***(3.170)
ROAD	−0.075(-0.096)	−1.074***(-0.346)	−1.148***(-0.369)	0.074*(0.041)	0.173*(0.092)	0.248**(0.100)
ACC	−0.135***(-3.070)	−0.505(-1.580)	−0.640*(-1.850)	−0.247***(-13.790)	0.916(0.980)	−0.155(-1.580)

Note: Z-statistics are reported in parenthesis, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TRA and lntravellers[2] on SO$_2$ is significant, and the coefficient of TRA is positive and lntravellers[2] is negative respectively. Indicating that there is an inverted U-shaped relationship between TRA and SO$_2$ in the local and neighboring cities. The effects of TRA on SO$_2$ is almost consistent with TRA. SO$_2$ first increases with TRA (INC) at a rate to reach a maximum, subsequently, SO$_2$ decreases at a rate as TRA (INC) continues to rise. For the direct effects of tourism on SO$_2$, we can obtain the curve maximum when the TRA is equal to 6.189 (i.e., number of tourist is about 4.874 million) or the INC equal to 3.301 (i.e., tourism income is about 0.271 ten billion yuan), which indicates that the rise of TRA (INC) can improve cities air quality when the TRA (INC) cross the "turning point" of the inverted U-shaped curve. Regardless of the average TRA or INC, China's tourism development has crossed the corresponding curve "turning point," which means that the current tourism development can help reduce local industrial SO$_2$ emissions in Chinese cities. For the indirect effects of tourism on SO$_2$, we can obtain the curve maximum when the TRA is equal to 3.110 (i.e., number of tourist is about 0.224 million) or the INC is equal to 1.209 (i.e., tourism income is about 0.034 ten billion yuan), which indicates that the rise of TRA (INC) has a significant spatial spillover effect on neighboring cities' SO$_2$ emissions. On average, the spatial spillover effects of current urban tourism development in China has crossed the "turning point" of the corresponding curve, which means that the development of China's tourism not only helps to reduce cities' industrial SO_2 emissions, but also contributes to reducing neighboring cities' industrial SO_2 emissions.

As we all know, the tourism industry is crucial to China's economic development, in this context, more and more cities have placed tourism development at a vital position in the adjustment of urban industrial structures. The development of green tourism economy has a significant contribution to the improvement of cities' environmental quality. In this process, it is easy to carry out spatial transmission through "learning effect" in neighboring cities due to the experience of tourism development in the region. And the neighboring cities can adjust their industrial structure through emulation and learning, resulting in a good spatial spillover effects.

For the control variables, the direct effects of POP on $PM_{2.5}$ and SO_2 is negative and significant in all models, while the indirect effects of POP on $PM_{2.5}$ and SO_2 was not significantly different from zero. Indicating that economic development, environmental awareness, and industrial structure optimization brought about by the scale effects of urban population can effectively alleviate regional air pollution (Lu and Feng, 2014). These results are in line with Fan and Zhao's (2019) research conclusions. The direct effects of ACC on $PM_{2.5}$ and SO_2 is negative and significant in all models, while the indirect effects of ACC on $PM_{2.5}$ and SO_2 was not significantly different from zero. Implying that the development of the service industry has relatively reduced the proportion of traditional polluting industries in the local economic development, thus effectively reducing local $PM_{2.5}$ and industrial SO_2 emissions. The effects of URB and ROAD on $PM_{2.5}$ and SO_2 do not have statistical significance. PGDP has a significant impact, and spatial spillover effect, on $PM_{2.5}$ and SO_2. Specifically, the direct effects of PGDP and $(PGDP)^2$ on $PM_{2.5}$ is significant and the coefficient of them is positive and negative, respectively, whether TRA or INC is an explanatory variable, showing that environmental Kuznets curve hypothesis is valid. In other words, there is an inverted U-shaped relationship between economic growth and $PM_{2.5}$ in China (Hao and Liu, 2016). The indirect effects of PGDP and $(PGDP)^2$ on $PM_{2.5}$ meets the environmental Kuznets curve hypothesis in the TRA model only. In the SO_2 model, the direct effects of PGDP and $(PGDP)^2$ on SO_2 are not statistically significant, while, the indirect effects of PGDP and $(PGDP)^2$ on SO_2 are significant and the coefficient of them is negative and positive, respectively, whether TRA or INC is an explanatory variable. Indicating that there is a U-shaped relationship between PGDP and the neighboring region's SO_2 emissions. Additionally, only when the PGDP is equal to 12.695 and 14.985 respectively in TRA and INC model, it will have a spatial spillover effect on SO_2. A possible explanation for this is, generally, that cities tend to emit pollution in local due to the higher tolerance of environmental pollution and weak government environmental regulations in the early stage of urban economic development. However, with the development of the local economy and the improvement of living conditions, cities tend to transfer high-pollution industries to neighboring cities, eventually resulting in increased pollution in neighboring cities. According to the descriptive statistics in this paper, in the TRA model, the results show that some developed cities in China have begun to carry out pollution industry transfer.

4.5. Robustness check

4.5.1. Inverse distance weight matrix

The spatial weight matrix used above is based on whether cities share the same administrative boundary. However, the assumption that cities without co-boundaries will not affect each other is too strong, especially in China, where the administrative boundary divisions of Chinese cities are extremely complicated. The inverse distance spatial weight matrix is set based on the spatial distance between cities, which effectively considers the interaction between the cities without co-boundaries but whose spatial distance is close. The regression results of inverse distance spatial weight matrix model shows in Table 5 Panel-A. The results show that the direct effect of TRA on $PM_{2.5}$ concentration is consistent with the results in Table 4. The direct effect of INC on $PM_{2.5}$ concentration is not significant. The direct effect of TRA and INC on SO_2 emissions is consistent with the results in Table 4. Unfortunately, the indirect effect of tourism development on $PM_{2.5}$ or SO_2 is not statistically significant, which means that different spatial weight metrics will result in inconsistent estimates to some extent.

4.5.2. Sub-sample

Beijing, Tianjin, Shanghai, and Chongqing were excluded in this section regression, because these four municipalities are in line with the province at the administrative level in China, the economic and population scale, the level of science, technology, and education is unmatched by ordinary prefecture-level cities. For example, Shanghai and Chongqing are among the cities with the most SO_2 emissions. Therefore, containing these four municipalities may lead to biased regression results. Table 5 Panel-B shows the regression results excluding these 4 municipalities. As we can see, the regression results is in line with Table 4, implying that the previous results are robust.

5. Moderating mechanism

We explore the moderating effects of high-speed rail (HSR) and travel resources (SPOT) on the relationship between tourism development and air pollution in Table 6. The effect of tourism development on $PM_{2.5}$ is not statistically significant after adding the moderating variables, so only the results about the effect of tourism development on SO_2 are reported in Table 6.

As shown in Table 6 Panel-A, in the TRA model, the direct and indirect effect of HSR are negative and significant. This result implies that HSR contributes to reducing cities' and their neighbors' industrial SO_2 emissions. The direct and indirect effect of the interaction term of TRA and HSR is positive and significant, while the quadratic interaction term is negative and significant, which indicates that there is an inverted U-shaped relationship between TRA and SO_2 after adding the moderating variable HSR. However, the indirect effect is not statistically significant for the tourism development as measured by INC.

The moderating effect of SPOT on industrial SO_2 emission is shown in Table 6 Panel-B. In the TRA or INC model, the direct effect of SPOT is negative and significant, which implies that cities that have rich natural tourism resources have less industrial SO_2 emissions. The direct effect of the interaction term of tourism development and SPOT is positive and significant, while the quadratic interaction term is negative and significant, regardless of the TRA or INC model. These results indicate that there is an inverted U-shaped relationship between TRA (INC) and SO_2 after adding the moderating variable (SPOT). But the indirect effect is not statistically significant in all models.

According to the above regression results, there have been less industrial SO_2 emissions in cities in which there has been high-speed rail and natural tourism resources are relatively abundant. Therefore, the mechanism (economic scale effect, technological innovation, industrial structure upgrading, and so on) of high-speed rail and 5A scenic spots impact on industrial SO_2 emission has been confirmed. As the effect of high-speed rail and 5A scenic spots is negative, meaning that the effect of tourism development

Table 5
Robustness check.

	$PM_{2.5}$			SO_2		
	Direct effects	**Indirect effects**	**Total effects**	**Direct effects**	**Indirect effects**	**Total effects**
Panel-A Inverse distance weight matrix						
TRA	2.385***(3.430)	−2.059(-0.480)	0.327(0.070)	2.384***(7.280)	9.719(1.030)	12.103(1.280)
$(TRA)^2$	−0.238***(-4.240)	0.183(0.540)	−0.054(-0.160)	−0.174***(-6.630)	−0.614(-1.100)	−0.788(-1.410)
INC	0.799**(2.210)	−33.160(-1.210)	−32.361(-1.170)	1.089***(6.790)	1.591(0.400)	2.679(0.660)
$(INC)^2$	−0.102**(-2.460)	1.841(0.680)	1.738(0.640)	−0.143***(-7.610)	−0.202(-0.510)	−0.345(-0.870)
Panel-B Sub-sample						
TRA	1.984***(2.620)	−0.522(-0.130)	1.462(0.340)	1.800***(5.900)	2.597**(2.440)	4.397***(3.910)
$(TRA)^2$	−0.185***(-3.130)	0.225(0.850)	0.040(0.140)	−0.143***(-5.860)	−0.300***(-4.150)	−0.443***(-5.880)
INC	0.291(0.760)	−5.725***(-2.660)	−5.433**(-2.320)	0.905***(6.020)	1.270**(2.250)	2.175***(3.600)
$(INC)^2$	−0.029(-0.680)	0.671***(3.060)	0.642***(2.700)	−0.149***(-8.500)	−0.238***(-4.110)	−0.387***(-6.300)

Note: Z-statistics are reported in parenthesis, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Control variables are included in all models.

Table 6
Moderating effects of high-speed rail and 5A scenic spots.

	Panel-A High-speed rail (HSR)			Panel-B 5A Scenic spots (SPOT)		
	Direct effects	Indirect effects	Total effects	Direct effects	Indirect effects	Total effects
TRA	2.077***(5.190)	−3.051**(-2.200)	−0.976(-0.670)	1.436***(4.240)	1.785(1.500)	3.221***(2.570)
$(TRA)^2$	−0.166***(-4.940)	0.180(1.600)	0.140(0.120)	−0.114***(-4.160)	−0.259***(-3.010)	−0.372***(-4.150)
HSR/SPOT	−0.032***(-5.980)	−0.050***(-2.720)	−0.818***(-4.210)	−25.992***(-8.780)	8.889(0.680)	−17.103(-1.230)
Inter1	0.008***(6.380)	0.015***(3.140)	0.023***(4.700)	6.727***(9.790)	−1.497(-0.490)	5.230(1.610)
$Inter1^2$	−0.0005***(-6.630)	−0.001***(-3.650)	−0.001***(-5.250)	−0.431***(-10.880)	0.040(0.230)	−0.391**(-2.070)
INC	1.014***(5.290)	−2.288**(-2.690)	−1.274(-1.420)	0.552***(3.260)	0.566(0.770)	1.118(1.440)
$(INC)^2$	−0.155***(-6.360)	0.171*(1.690)	0.015(0.140)	−0.099***(-4.900)	−0.209***(-2.780)	−0.308***(-3.900)
HSR/SPOT	−0.008***(-4.440)	−0.005(-0.830)	−0.014**(-2.090)	−4.502***(-3.800)	8.168(1.590)	3.666(0.670)
Inter2	0.003***(5.170)	0.003(1.530)	0.007***(2.970)	1.945***(5.150)	−2.500(-1.540)	−0.556(-0.320)
$Inter2^2$	−0.0003***(-5.460)	−0.0004**(-2.540)	−0.0008***(-4.030)	−0.200***(-6.730)	0.167(1.330)	−0.034(-0.250)

Note: Z-statistics are reported in parenthesis, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Inter and Inter^{21} represent an interaction term and quadratic interaction term of the moderating variables (HSR, SPOT) and independent variables (TRA, INC) respectively. Inter1 is an interaction term of the moderating variables and TRA, Inter2 is an interaction term of the moderating variables and INC. Control variables are included in all models.

on urban industrial SO_2 emissions has been enhanced. In other words, high-speed rail and 5A scenic spots increased the positive impact when the marginal effect of tourism development on SO_2 is positive. The environmental externalities are obvious in the early stage of tourism development, while the improvement of high-speed rail and the abundance of tourism resources will further promote the expansion of tourism, and lead to an increase in SO_2 emissions. The high-speed rail and 5A scenic spots increases the negative impact when the marginal effect of tourism development on SO_2 is negative. Implying that the environmental effects of high-speed rail and tourism resources are appearing after tourism development has crossed the “turning point” of environmental pollution curve.

It is necessary to explain why the effect of tourism development on $PM_{2.5}$ is not statistically significant here. Although in theory high-speed rail has significant impacts on urban air quality in both direct and indirect aspects, the impacts are negligible since private cars are still the preferred mode of transportation.

6. Conclusion and policy implications

Tourism has been considered as the new engine for job creation, in recent years. This perspective has led to increased consumption and accelerated economic growth. However, the development of tourism often generates environmental externalities, especially by causing air pollution. Given its salience it is regrettable that the relationship between tourism development and air pollution remains unclear. Prior studies found mixed results on the effect of tourism on air pollution. This paper fills this lacuna by examining the spatial spillovers effect of tourism on air pollution measured by $PM_{2.5}$ and SO_2 based on a panel data of 285 prefecture-level cities in China from 2005 to 2017. The GNS results are as follows:

1) There is a significant inverted U-shaped relationship between tourism development and local $PM_{2.5}$ concentrations while a significant U-shaped relationship exists in tourism development and neighboring cities’ $PM_{2.5}$ concentrations.
2) The direct effect and indirect effect of tourism development on SO_2 emissions is significant, and all shows an inverted U-shaped relationship between tourism development and SO_2 emissions.

3) Urban high-speed rail (HSR) and tourism resources(SPOT) play an important moderating role between tourism development and China’s urban industrial SO_2 emissions. Specifically, tourism infrastructure construction (longer HSR and more SPOT) can not only reduce cities’ and neighboring cities’ industrial SO_2 emissions, also enhance the impact of tourism development on industrial SO_2 emissions.

The above results allow us to draw the following policy implications:

1)The relationship between tourism and local $PM_{2.5}$ concentrations shows an inverted U-shape, while tourism and neighbors’ $PM_{2.5}$ concentrations shows an U-shape. It was commonly believed that industrial production was the main source of environmental pollution. But in fact, the change of residents’ lifestyle is also an important aspect that causes environmental pollution. As a modern leisure and entertainment, travel is becoming more and more popular in people’s life, but it’s pressure on the ecological environment cannot be ignored. Especially the transportation and accommodation problems accompanying travel are obvious. Therefore, developing green transportation and encouraging green travel in future are priority to reduce $PM_{2.5}$ emissions. Meanwhile, the phenomenon that tourism pollution transfer by neighboring cities are still an obvious challenge. Preventing the transfer of tourism pollution requires more policies and measures.

2)The direct effect and spatial spillover effect of tourism development on SO_2 emissions shows an inverted U-shape. Fortunately, no matter the direct or indirect effect of tourism development on SO_2 emissions are crossed the “turning point” of inverted U-shape on average, suggesting that the cities’ and neighboring cities’ tourism development helps reduce SO_2 emission in current stage. But, however, the development of tourism is unbalanced in the developed and developing cities in China. There are so many cities may not crossed the “turning point”. Therefore, it is imperative to accelerate the transformation of the tourism industry development model of developing cities and introduce related policy to encourage the development of green tourism economies in developing cities.

3)There is a significant moderating effect of high-speed rail and tourism resources on the relationship between tourism development and industrial SO_2 emissions. For the cities governments, the most urgent task is to appropriately increasing investment in urban high-speed rail to improve the urban transportation infrastructure network. A well-developed public transportation network can largely replace private transportation and help reduce traffic pollution emissions from travel. At the same time, it is necessary to give full play to the environmental effects of 5A-scenic spots, and strengthen the management in order to develop green tourism.

CRediT authorship contribution statement

Jingjing Zeng: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Yonglin Wen:** Data curation, Writing - original draft. **Chao Bi:** Software, Visualization, Investigation. **Richard Feiock:** Validation, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[2] It should be noted that due to the high-speed rail mileage data of each city is difficult to obtain, this paper use the high-speed rail mileage data of the provinces where one city located as the proxy of high-speed rail mileage of city.

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