



The spatial effect of tourism economic development on regional ecological efficiency

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Abstract

The process of tourism economic development is accompanied by the consumption of energy and environment. It is of a big significance to measure the level of tourism economic development and regional eco-efficiency correctly to clarify the relationship between them, as it contributes to realizing the high-quality development of the tourism economy and the construction of “beautiful China”. On the basis of the panel data of China’s 30 provinces and cities from 2002 to 2016, the paper intends to evaluate the regional eco-efficiency and tourism economic development level by using the super-efficiency DEA model and the grey entropy weight method, and then construct spatial panel econometric model which is based on the previous data to deeply discuss the influence of tourism economy development on regional ecological efficiency and its spatial effect. The research shows that (1) regional ecological efficiency has significant spatial dependence and spatial aggregation characteristics. With the passing of time, this kind of positive spatial autocorrelation is gradually strengthened. (2) In the long-term development, tourism economic development and regional ecological efficiency show a more obvious “Kuznets curve” effect. (3) The “U”-curve relationship between urbanization, environmental regulation, and regional eco-efficiency was confirmed. (4) In the process of tourism economic transformation and development, industrial pollution control, environmental regulation, technological level, urbanization, and investment openness are the main factors that affect the improvement of ecological efficiency in the local region. (5) Tourism economic development and urbanization levels have different spatial spillover effects in different periods, while investment openness has obvious positive spillover effects.

Keywords Tourism economic development · Regional ecological efficiency · Kuznets curve · Spillover effect · Spatial panel measurement model

Introduction

As China’s economic development enters a new period, the economic structure and development mode have undergone corresponding adjustment and transformation. The report of the 18th National Congress of the Communist Party of China clearly pointed out that the transition from high-speed development to high-quality development is a basic feature of the new period, and the 19th National Congress report further indicated that China’s economy has changed from the high-

speed growth stage to the high-quality development stage. In the process of economic development, focusing on the unification of economic development and ecological efficiency is not only the inevitable choice to realize the efficiency of economic growth but also the requirement of promoting the reform of the ecological civilization system and building a “beautiful China”. Compared with other industries, tourism, as an important part of the tertiary industry, has the inherent advantage of “strong correlation, low consumption, and high output”. According to the statistics of the Ministry of Culture and Tourism, China’s total tourism revenue in 2018 is 5.97 trillion yuan, accounting for about 11.04% of GDP. However, the over-reliance on resource elements to invest in the pursuit of short-term performance has made the problems of low output and degradation of the ecological environment increasingly prominent. The tourism industry will have positive or negative effects on the ecological environment through two different paths of protection and suppression (Zhu 2017).

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Therefore, how to correctly grasp the impact of tourism economic development on ecological efficiency, and coordinate the relationship between sustained and stable economic growth and ecological environment protection has become an important practical problem currently facing. In this context, the spatial layout and evolution of China's tourism economy and its impact on the economy and ecology are explored. This will help accelerate the transformation and upgrading of the tourism industry, promote the development of high-quality tourism services, vigorously improve the quality and efficiency of the industry, enhance the virtuous circle between tourism-economy-ecology, and then realize the organic unification of economic, ecological and social benefits. It has important theoretical reference value and practical guiding significance.

Literature review

Since the term regional ecological efficiency was first proposed by Schaltegger and Sturm, its connotation definition has been continuously expanded. At present, a large number of scholars have taken it as an important index to measure the impact of industrial economic activities on the ecological environment. Existing literature has researched the regional ecological efficiency from the aspects of conceptual connotation, measurement methods, and application fields. From the perspective of conceptual development, the definition of ecological efficiency has been continuously enriched. From the single ratio of economic value-added and environmental impact to the perspective of input and output, whether an economic activity is effective or not (Schaltegger 1990; WBCSD 1996; Sauvans and UNCTAD 2003; OECD Proceedings 1999). In 1998, the World Economic Cooperation and Development Organization extended its concept to enterprises, governments, and even the entire economic system. Most domestic scholars, based on the definition of the World Business Council for Sustainable Development, focused on the sustainable development of the economy and society. They believe that ecological efficiency should reflect the intensive characteristics between inputs and outputs of production technology innovation (Li et al. 2000), the maximum service output that society can achieve when the optimal business objectives and the best environmental goals are achieved at the same time (Mao et al. 2004). From the research method, by the ratio method of economy and environment to factor analysis, hierarchical analysis (Huang 2015; Fang et al. 2011; Zhang et al. 2018), the complexity of economic operation structure and the defects of traditional evaluation methods put forward higher requirements for measurement methods. In order to obtain more accurate results, *data envelopment analysis* (DEA) and ecological footprint analysis are widely used in the study of ecological efficiency. Yang et al. (2013), Liu et al. (2016), Li and Luo (2016) respectively used the BCC model and the

super-efficiency DEA model to measure the ecological efficiency at different scales. From the perspective of the application, ecological efficiency is mainly concentrated in four aspects: enterprises, products, industries, and regions. Among them, there are many studies on tourism ecological efficiency. Liu and Lu (2016) defined tourism eco-efficiency as the ratio between the value of products provided by the tourism industry and the consumption of environmental expenditure. On this basis, Peng et al. (2017) used the SBM-DEA model to comprehensively evaluate the tourism ecological efficiency of the Huangshan Scenic Area.

Tourism economic development, as an important index to measure the development of the tourism industry, has always been a hot topic in academic research. Most of the existing researches focus on the measurement of the level of regional tourism economic development (Wu 2018; Dong et al. 2018; Mu et al. 2019) and the discussion of the factors affecting the development of tourism economy (Wu and Song 2018; Zhu et al. 2019). In recent years, some scholars have incorporated the ecological environment or ecological efficiency into the study of tourism economic development as a result of the degradation of the ecological environment, the endangerment of rare species, and the depletion of natural resources. Zou (2019) studied the relationship between the development of Chongqing's tourism economy and the ecological environment from a micro-level. The model concluded that there was a significant correlation between the ecological environment indicators and the tourism economy characterized by tourism income. In order to further reveal the relationship between the tourism economy and the ecological environment, Wang et al. (2019) confirmed the interactive stress relationship between them based on a double index model. From the perspective of sustainable development, Wang and Liu (2019) broke the previous macro-qualitative description, and for the first time, with the help of an econometric model, outlined the spatial and temporal evolution trajectory of ecological efficiency and tourism economic development level. On this basis, he explores the interactive response relationship between them.

Through a review of the literature, it can be found that few studies have explored the impact of the development of the tourism economy on the ecological efficiency from a spatial perspective. The existing results are concentrated in the measurement of ecological efficiency and the evaluation of the ecological efficiency of the tourism industry, while the research on the relationship between tourism economic development and ecological efficiency is still in the preliminary exploration stage. In view of this, based on the methods and ideas of previous research, this paper first uses the super-efficiency DEA to measure the regional ecological efficiency of 30 provinces and cities in China, and second, combines the entropy weight method with the grey correlation method to make a dynamic evaluation of the level of tourism economic development in the sample area, and then introduces control

variables. The spatial panel data model is used to deeply study the impact of tourism economic development on regional ecological efficiency, in order to provide useful policy references for China’s tourism economic development and ecological environmental protection.

Measurement of regional ecological efficiency

Economists Andersen and Petersen (1993) proposed a super-efficiency model based on the traditional CCR model, which can effectively solve the problem of how to make further evaluations when multiple decision-making units are at the forefront of production at the same time. The basic idea of the decision-making unit (DMU) of the super-efficiency DEA model is the exclusion mechanism. For the effective DMU, it is excluded first, while for the ineffective DMU, keep the production frontier unchanged, and then increase the proportion of investment for the effective DMU proportionally, so that the production frontier shifts backward. Finally, the specific values of effective DMU can be measured more precisely. Assuming that there are n decision units, each of which has m inputs and s outputs, the super-efficient DEA model expression is as follows:

$$\begin{cases} \text{Min} [\theta - \varepsilon (\sum_{i=1}^m s_i^- + \sum_{r=1}^s s_r^+)] \\ \text{s.t.} \\ \sum_{k=1}^n x_k \eta_k - s^- = \theta x_p \\ k \neq p \\ \sum_{K=1}^n Y_k \eta_k - s^+ = Y_p \\ K \neq p \\ \eta_k \geq 0, k = 1, 2, \dots, m; s^+ \geq 0, s^- \geq 0 \end{cases}$$

Among them, X_k and Y_K respectively represent the input variable and output variable of the k -th decision unit, which can be expressed as a matrix: $X_k = (x_{1k}, x_{2k}, \dots, x_{mk})^T$, $Y_k = (y_{1k}, y_{2k}, \dots, y_{sk})^T$, θ is the efficiency value of the decision unit. Referring to the evaluation system of ecological efficiency constructed by Luo et al. (2013) and E and E and Du (2015) combined with the scientific and available data. This paper considers energy consumption, total water use, built area, employment, wastewater emissions, chemical oxygen demand emissions, sulfur dioxide emissions, soot emissions, and industrial solid waste generation as input variables. The regional gross domestic product (GDP) calculated from the base period of 2002 is used as the output variable. To construct a multi-input, single-output evaluation system of regional ecological efficiency, as shown in Table 1.

The data of each indicator variable in Table 1 are derived from China Statistical Yearbook, China Environmental Yearbook, China Energy Statistical Yearbook, and China Water Resources Bulletin. Due to the lack of data in Tibet, the research object of this paper is the remaining 30 provinces and regions in mainland China. The regional ecological

efficiency was measured using MYDEA 1.0.5 and an input-oriented super-efficiency DEA model. The specific results are shown in Table 2.

The results of Fig. 1 show that the ecological efficiency of most provinces and cities in China has shown a significant upward trend. China’s overall regional ecological efficiency has been significantly improved due to the emphasis on the environmental protection of resources in a state of sustained and stable economic development. However, from a meso-level perspective, there are large differences in ecological efficiency between regions. Beijing, Tianjin, Shanghai, and Fujian are at the forefront of effective ecological efficiency, in addition to Jiangsu, Zhejiang, Shandong, Guangdong, Hainan, and other southeast provinces, the rest of the central and western, most of the ecological efficiency is still at a low level.

Dynamic measurement of tourism economic development level

Index system construction

The development of the tourism economy is affected by many factors. Generally speaking, the development level of the regional tourism economy includes both the inherent requirements of tourism competitiveness and the external manifestation of tourism economic benefits. According to the diamond model proposed by Michael E. Porter (Michael 1990), the factors affecting the competitiveness of regional tourism include not only primary production factors such as the abundance of tourism resources, ecological environment, and geographic regions but also advanced factors such as transportation facilities, human resources, travel agency development level, urban greening, and construction, which are more important for the formation of industrial advantages. Accordingly, on the basis of the dynamic evaluation system of the competitiveness of the tourism industry constructed by Su and Huang (2010), this paper constructs the multi-level evaluation system of facility level, development of an intermediary organization, human capital level, and tourism economic benefits according to the principles of particularity, hierarchy, region, and data availability selected by evaluation index. The specific framework structure of the system can be seen in Table 3.

The data of the above indicators are derived from China Tourism Statistical Yearbook, New China Statistical Data Collection for 60 Years, and China Environment Yearbook. Among them, the total tourism income is the sum of the foreign exchange income of tourism after exchange rate conversion and domestic tourism income. Due to the lack of data on the area of formed towns in Beijing and Tianjin in some years, this paper uses the logarithm of the index variables, linear interpolation, and then takes the antilog to supplement the missing values.

Table 1 Evaluation index system of regional ecological efficiency

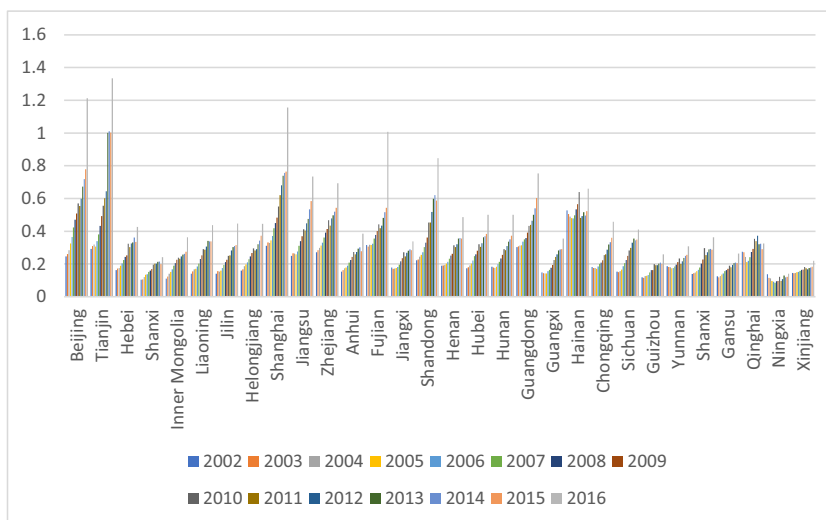
Index	Category	Index composition	Details
Invest	Resource consumption	Energy	Total energy consumption
		Water resources	Total water use
		Land	Built-up area
	Environmental pollution	Human Resources	employed population
		Waste water	Wastewater emissions COD emissions
		Exhaust gas	SO ₂ emissions Soot emissions
Output		Exhaust solids	Production of industrial solid waste
		Total economic development	Regional GDP

Table 2 Results of regional ecological efficiency evaluation in 30 provinces and cities in China

Region	Regional ecological efficiency in different years									
	2002	2006	2010	2011	2012	2013	2014	2015	2016	
Beijing	0.246	0.365	0.570	0.555	0.598	0.673	0.719	0.779	1.213	
Tianjin	0.293	0.340	0.556	0.601	0.645	1.001	1.011	1.002	1.335	
Hebei	0.163	0.204	0.324	0.303	0.325	0.332	0.362	0.335	0.427	
Shanxi	0.105	0.138	0.196	0.203	0.202	0.213	0.215	0.199	0.241	
Inner Mongolia	0.111	0.167	0.238	0.233	0.246	0.258	0.263	0.275	0.364	
Liaoning	0.141	0.185	0.290	0.288	0.307	0.341	0.338	0.338	0.438	
Jilin	0.140	0.175	0.249	0.252	0.282	0.303	0.309	0.316	0.447	
Helongjiang	0.160	0.210	0.296	0.282	0.291	0.321	0.343	0.372	0.446	
Shanghai	0.311	0.371	0.551	0.621	0.681	0.739	0.756	0.764	1.156	
Jiangsu	0.249	0.277	0.412	0.405	0.448	0.476	0.533	0.585	0.734	
Zhejiang	0.272	0.330	0.467	0.434	0.479	0.498	0.520	0.543	0.693	
Anhui	0.153	0.190	0.274	0.259	0.274	0.294	0.301	0.278	0.385	
Fujian	0.316	0.323	0.442	0.418	0.434	0.482	0.517	0.543	1.007	
Jiangxi	0.178	0.182	0.271	0.247	0.268	0.281	0.289	0.285	0.338	
Shandong	0.222	0.272	0.454	0.453	0.518	0.598	0.620	0.588	0.846	
Henan	0.189	0.213	0.314	0.304	0.320	0.355	0.358	0.356	0.487	
Hubei	0.174	0.221	0.321	0.305	0.327	0.363	0.370	0.383	0.501	
Hunan	0.183	0.199	0.290	0.284	0.309	0.337	0.351	0.372	0.500	
Guangdong	0.304	0.336	0.433	0.439	0.464	0.501	0.540	0.603	0.754	
Guangxi	0.148	0.157	0.225	0.244	0.259	0.283	0.289	0.290	0.355	
Hainan	0.527	0.479	0.639	0.481	0.493	0.516	0.496	0.522	0.660	
Chongqing	0.181	0.185	0.254	0.259	0.287	0.319	0.334	0.360	0.458	
Sichuan	0.154	0.186	0.283	0.299	0.330	0.356	0.345	0.349	0.410	
Guizhou	0.118	0.133	0.199	0.193	0.192	0.202	0.209	0.200	0.259	
Yunnan	0.187	0.175	0.234	0.201	0.217	0.237	0.250	0.256	0.308	
Shanxi	0.139	0.165	0.297	0.255	0.272	0.289	0.293	0.288	0.363	
Gansu	0.125	0.143	0.190	0.180	0.195	0.205	0.209	0.206	0.264	
Qinghai	0.275	0.219	0.353	0.340	0.373	0.320	0.323	0.290	0.325	
Ningxia	0.138	0.091	0.122	0.097	0.107	0.130	0.118	0.122	0.141	
Xinjiang	0.146	0.151	0.181	0.174	0.168	0.176	0.179	0.184	0.219	

Limited to the layout, only some years are displayed; all years are shown in the attached table, the same as below.

Fig. 1 Evaluation results of regional ecological efficiency from 2002 to 2016



Research method

Entropy weight method

The entropy weight method uses the intensity and unevenness of the data itself to reflect the importance of the indicator. Unlike the expert scoring method, it is an objective weighting method. Assuming that there are *n* evaluated objects and *p* evaluation indexes, the calculation process of the entropy weight method is as follows:

First, normalize the raw data. Since the normalized result may have a value of 0, the formula is as follows by the effect coefficient method:

$$A_{ij} = \{ [x_{ij} - \min(x_{ij})] / [\max(x_{ij}) - \min(x_{ij})] \} * 0.9 + 0.1 \quad (1 \leq i \leq n)$$

Among them, x_{ij} represents the *j*-th evaluation index of the *i*-th evaluated province and city.

Then, the entropy value of the *j*-th evaluated index is defined as:

$$H_j = -\frac{1}{n(n)} \sum_{i=1}^n m_{ij} \ln m_{ij}, \quad \text{其中 } m_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}}$$

Finally, on the basis of defining entropy, the indicator entropy weight is further calculated:

$$\omega_j = \frac{1 - H_j}{\sum_{j=1}^p (1 - H_j)}$$

The panel data of the level of tourism economic development in China's provinces and cities from 2002 to 2016 were

Table 3 Evaluation index system of tourism economic development level

Target layer	Criterion layer	Indicator layer
Tourism economic development level	Facility level	Public transport vehicles per 10,000 people (X1)
		Railway operating mileage per 10,000 people (X2)
		Star-rated hotels per 10,000 people (X3)
		Per capita green space in formed towns (X4)
		Public toilets per 10,000 people (X5)
	Development of intermediary organizations	Travel agency average income (X6)
		Average number of people received by travel agencies (X7)
	Human capital level	Proportion of tourism universities (X8)
	Economic benefits of tourism	Total tourism income (X9)
		Proportion of output value of tertiary industry (X10)
		Star hotel staff productivity (X11)

divided into 15 cross-sections, and the weights of each indicator were obtained using the above-mentioned formula. The results are shown in Table 4. It can be found that the value range of the entropy weight is between 0 and 1, and the sum of the entropy weights of each section is 1. From the perspective of reflecting information, the size of entropy weight depends on how much useful information the indicator provides, so compared with other subjective weighting methods, the value of entropy weighting is more accurate.

Grey association method under the convergence of excellence

According to the research of Zhao et al. (2018), Li et al. (2016), and other scholars, in the long run, China’s tourism economy is in a gradual growth trend. Based on this characteristic, this paper learns from the methods of Pan et al. (2013), through comparison to select the optimal sequence values of this period and the previous period. The similarity between the current sequence and the optimal sequence is judged by the grey association method, so as to make a comprehensive evaluation of tourism economic development from a dynamic perspective.

The first step is to select the optimal state sequence $z(t)^*$ as the reference sequence from this year and the previous year. Considering that the indicators used to construct the evaluation system in this paper are all positive indicators, so the process of selecting the optimal sequence is essentially the process of maximizing the evaluation indicators, the specific formula is as follows:

$$Z(t)^* = \begin{cases} \max[Z_{i1}(t), Z_{i2}(t), \dots, Z_{ij}(t), \dots, Z_{ip}(t)] & t = 1 \\ \max\{Z(t-1)^*, \max[Z_{i1}(t), \dots, Z_{ij}(t), \dots, Z_{ip}(t)]\} & t > 1 \end{cases}$$

The second step is to nondimensionalize the cross-sectional data and the optimal state sequence of the current period. Let the value of the optimal series be 1, the data for the rest of regions and the original optimal sequence value are divided:

$$Z_{ij}(t) = Z_{ij}(t) / Z(t)^*$$

The third step is to calculate the correlation coefficient based on the normalized optimal sequence and the sequence of each region:

$$\xi_i(j)(t) = \frac{\min\{\min(|Z_j(t)^* - Z_{ij}(t)|)\} + \rho \cdot \max\{\max(|Z_j(t)^* - Z_{ij}(t)|)\}}{|Z_j(t)^* - Z_{ij}(t)| + \rho \cdot \max\{\max(|Z_j(t)^* - Z_{ij}(t)|)\}}$$

$$(i = 1, 2n; j = 1, 2p)$$

Among them, ρ is a resolution coefficient, and its value is between 0 and 1. When the value of ρ is smaller, the difference between the correlation coefficients is larger. Here, ρ is set to 0.5 according to a common practice.

The fourth step, combined with the weight obtained by the entropy weight method, the comprehensive correlation degree of the trend is calculated:

$$L(t) = \sum_{j=1}^p [\omega_j(t) \times \xi_i(j)(t)]$$

According to the above four steps, the results obtained by using excel are as follows.

Figure 2 is a histogram drawn from the results of all years in Table 5. Based on the polyline formed by the average of different regions over the years, it can be seen that Beijing’s tourism economic development level is significantly higher

Table 4 Calculation results of entropy method

Index/year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2002	0.062 7	0.116 9	0.142 5	0.026 7	0.061 7	0.200 7	0.186 5	0.026 1	0.039 4	0.006 1	0.130 6
2003	0.067 4	0.113 8	0.130 1	0.015 1	0.052 6	0.207 8	0.203 1	0.028 8	0.047 9	0.006 2	0.127 3
2004	0.052 4	0.119 4	0.121 8	0.013 8	0.050 3	0.235 2	0.175 2	0.028 0	0.064 7	0.007 8	0.131 5
2005	0.039 3	0.133 2	0.132 4	0.015 3	0.054 0	0.240 3	0.156 4	0.024 5	0.050 0	0.009 8	0.144 8
2006	0.041 6	0.150 7	0.116 4	0.012 0	0.060 7	0.250 8	0.154 9	0.026 5	0.051 7	0.010 1	0.124 7
2007	0.032 2	0.160 1	0.126 6	0.010 3	0.059 3	0.248 4	0.159 3	0.017 3	0.046 5	0.012 0	0.128 0
2008	0.031 7	0.175 8	0.118 8	0.011 0	0.055 5	0.255 4	0.147 5	0.021 4	0.038 8	0.014 9	0.129 2
2009	0.033 4	0.169 6	0.093 1	0.013 0	0.052 6	0.244 2	0.205 9	0.025 1	0.025 8	0.013 9	0.123 4
2010	0.020 6	0.191 1	0.087 7	0.016 4	0.043 0	0.269 9	0.158 9	0.030 1	0.041 5	0.016 7	0.124 1
2011	0.025 1	0.197 7	0.073 1	0.018 2	0.037 4	0.220 6	0.218 6	0.031 9	0.037 0	0.019 7	0.120 7
2012	0.027 0	0.203 4	0.079 8	0.016 8	0.036 8	0.248 5	0.187 3	0.032 9	0.032 8	0.019 5	0.115 3
2013	0.025 4	0.196 9	0.080 4	0.016 3	0.034 0	0.281 2	0.179 0	0.023 0	0.032 4	0.019 4	0.112 0
2014	0.025 4	0.190 2	0.083 3	0.016 2	0.035 9	0.280 0	0.170 1	0.021 8	0.049 9	0.016 6	0.110 5
2015	0.024 1	0.204 1	0.096 8	0.016 7	0.038 8	0.280 6	0.152 0	0.017 8	0.052 0	0.014 9	0.102 2
2016	0.023 9	0.209 9	0.069 5	0.017 1	0.034 7	0.284 4	0.169 3	0.020 2	0.057 9	0.014 3	0.098 6

than other regions, which is listed as the “first echelon” of the level of tourism economic development. Shanghai, Guangdong, Inner Mongolia, and Qinghai in China’s east and west sides in the high level of tourism economic development region, located in the “second echelon”. The rest of the region’s tourism economic development level is low, the comprehensive correlation degree of optimization is basically below 0.5, which is in the “third echelon”. From the distribution of tourism development level, the above five provinces and cities in China have formed a situation of “one super and many strong” in China, and the gap between the echelons is large. From the long-term development point of view, the levels of tourism economic development in Beijing and Guangdong show a clear trend of fluctuation and decline, Among the remaining “many strong” provinces and autonomous regions, the development level of tourism economy in Inner Mongolia showed steady and positive growth, and the volatility of Shanghai and Qinghai was relatively strong. In the “third echelon”, the level of tourism economy development increased for two years in Sichuan, while the overall development level of other regions was relatively stable. Regional differences are gradually narrowing.

Spatial econometric analysis

Econometric model and sample data

Space weight matrix setting When regions with similar locations have similar variable values, it means that the variables have spatial autocorrelation. The methods for measuring spatial autocorrelation are usually Moran’s *I*, Geary’s *I*, and Getis–Ord index. This article uses Moran’s *I* evaluation method, the calculation formula is:

$$\text{Moran's } I = \frac{\sum_{i=1}^n \sum_{j=1}^n \omega_{ij} (x_i - \bar{x})(x_j - \bar{x})}{s^2 \sum_{i=1}^n \sum_{j=1}^n \omega_{ij}}$$

In the above formula, s^2 is the sample variance, and w_{ij} is the (i, j) element in the spatial weight matrix, which represents the distance between area *i* and area *j*. According to the different definitions of distance, the spatial weight matrix can be divided into geographic adjacency matrix, geographic distance weight matrix, and economic distance matrix. This paper mainly uses a geographic distance weight matrix, taking into account the comparability and economic factors included in regional ecological efficiency. The adjacency matrix and the economic distance matrix are introduced to facilitate comparison.

The value of the geographic adjacency weight matrix w'_{ij} is based on whether there are identical boundaries between regions. if area *i* is adjacent to area *j*, it is recorded as $w'_{ij} = 1(i \neq j)$, otherwise $w'_{ij} = 0(i = j)$.

The geographical distance weight matrix w''_{ij} takes the inverse of the distance between two places as the spatial weight. Compared with the geographically adjacent weighting matrix, this setting holds that even the non-adjacent areas also have the possibility of mutual influence, and this effect decreases with the increase of distance, which is more in line with the actual situation in the study. The expression is:

$$w''_{ij} = \begin{cases} \frac{1}{d^2}, & i \neq j \\ 0, & i = j \end{cases}$$

The economic weighting matrix, w''' , uses the difference in GDP per capita as an indicator of the “economic distance” between regions:

Fig. 2 Evaluation results of tourism economic development level from 2002 to 2016

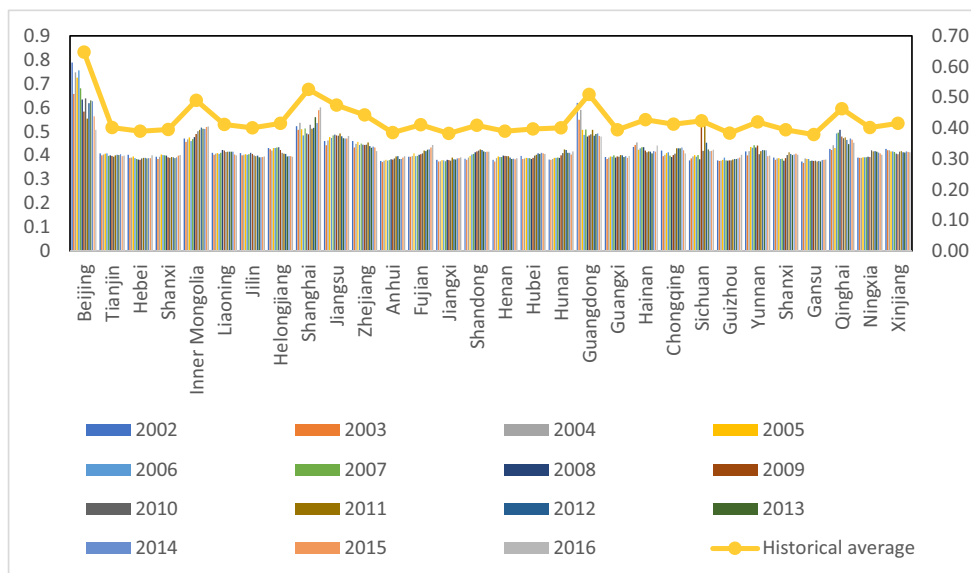


Table 5 Evaluation results of tourism economic development levels in 30 provinces and cities in China

Province	Development level of tourism economy in different years								
	2002	2006	2010	2011	2012	2013	2014	2015	2016
Beijing	0.788	0.757	0.638	0.554	0.619	0.631	0.627	0.564	0.508
Tianjin	0.408	0.409	0.395	0.401	0.403	0.402	0.405	0.397	0.399
Hebei	0.403	0.389	0.388	0.390	0.390	0.388	0.389	0.389	0.400
Shanxi	0.395	0.401	0.390	0.394	0.393	0.388	0.393	0.399	0.402
Inner Mongolia	0.470	0.461	0.501	0.508	0.516	0.512	0.510	0.518	0.521
Liaoning	0.411	0.406	0.414	0.416	0.416	0.415	0.416	0.404	0.400
Jilin	0.410	0.402	0.400	0.396	0.399	0.392	0.392	0.393	0.396
Heilongjiang	0.431	0.431	0.410	0.408	0.407	0.396	0.397	0.396	0.394
Shanghai	0.523	0.484	0.528	0.512	0.515	0.560	0.536	0.589	0.602
Jiangsu	0.460	0.473	0.483	0.492	0.481	0.473	0.470	0.471	0.481
Zhejiang	0.461	0.444	0.446	0.454	0.439	0.432	0.436	0.434	0.418
Anhui	0.377	0.378	0.387	0.396	0.396	0.386	0.386	0.391	0.397
Fujian	0.395	0.397	0.408	0.420	0.418	0.423	0.425	0.433	0.444
Jiangxi	0.381	0.379	0.378	0.391	0.384	0.382	0.387	0.389	0.392
Shandong	0.387	0.404	0.421	0.425	0.423	0.417	0.415	0.416	0.415
Henan	0.382	0.393	0.397	0.397	0.391	0.386	0.386	0.384	0.389
Hubei	0.398	0.389	0.399	0.403	0.408	0.406	0.411	0.408	0.406
Hunan	0.382	0.390	0.409	0.425	0.423	0.411	0.412	0.404	0.417
Guangdong	0.620	0.487	0.489	0.507	0.483	0.490	0.492	0.481	0.479
Guangxi	0.394	0.394	0.395	0.402	0.400	0.394	0.397	0.390	0.398
Hainan	0.436	0.430	0.414	0.417	0.415	0.409	0.418	0.416	0.442
Chongqing	0.421	0.414	0.407	0.429	0.429	0.430	0.433	0.421	0.408
Sichuan	0.379	0.394	0.419	0.540	0.453	0.425	0.418	0.419	0.424
Guizhou	0.379	0.391	0.380	0.382	0.386	0.386	0.387	0.391	0.403
Yunnan	0.417	0.432	0.406	0.418	0.422	0.422	0.421	0.397	0.399
Shanxi	0.391	0.385	0.401	0.413	0.406	0.401	0.403	0.407	0.403
Gansu	0.375	0.385	0.378	0.375	0.377	0.375	0.381	0.382	0.382
Qinghai	0.428	0.491	0.472	0.475	0.465	0.447	0.471	0.467	0.454
Ningxia	0.391	0.392	0.422	0.417	0.418	0.415	0.413	0.408	0.403
Xinjiang	0.427	0.417	0.416	0.419	0.413	0.412	0.417	0.415	0.413

$$w_{ij} = \begin{cases} \frac{1}{|\bar{Y}_i - \bar{Y}_j|}, & (i \neq j) \\ 0, & (i = j) \end{cases}$$

Among them, \bar{Y}_i is the average GDP of the region i from 2002 to 2016, with 2002 as the base period.

Space panel model construction

In order to systematically study the impact of tourism economic development on regional ecological efficiency, this paper includes other variables that have been extensively studied in the spatial panel model analysis and have a significant impact on regional ecological efficiency: industrial pollution control, environmental

regulation, technical level, urbanization level, and investment openness.

Based on the spatial effect of variables, three commonly used spatial econometric models are considered in this paper, namely, the space Dubin model (SDM), the spatial error model (SEM), and the spatial lag model (SLM). The SLM model does not consider the spatial lag of explanatory variables in the SDM model, while the SEM model excludes the influence of spatial lag items of interpreted variables on the basis of the SLM model. Therefore, both are special forms of SDM models. In this paper, the general SDM model is selected. In addition, considering that the control variables may have heteroscedasticity, they are treated as logarithms. The SDM expression is as follows:

$$\begin{aligned}
 REE_{it} = & \alpha + \beta WREE_{it} + b_1 TE_{it} + b_2 (TE_{it})^2 + b_3 \text{Control} \\
 & + c_1 WTE_{it} + c_2 W(TE_{it})^2 + c_3 W\text{Control} + \mu_i \\
 & + v_i + \varepsilon_{it}
 \end{aligned}$$

$$\varepsilon_{it} \sim N(0, \sigma_{it}^2 \ln)$$

Among them, REE_{it} represents the ecological efficiency of the i -th province in the t -year. TE is the explanatory variable—the level of tourism economic development. Control represents control variables, including industrial pollution control (lnicd), environmental regulation (lner), technical level (lnl), urbanization level (lnul) and investment openness (lnip). W is the spatial weight matrix, μ_i and v_i are the individual and time effects of region i , and ε_{it} is the error term.

Decomposition method of spatial effect

Lesage and Pace (2009) proposed that when the coefficient of the lag term of the explanatory variable space is significantly different from zero, in addition to the explanatory variable affecting the explained variable, the explained variables will interact with each other until a new equilibrium is reached. There is a systematic bias in coefficients of the spatial Durbin model to measure the spillover effects of tourism economic development. Therefore, referring to the spatial effect decomposition method of Wang et al. (2016), this paper decomposes the above formula in the form of partial differential, which can be written as a matrix:

$$Y = [1-\lambda w]^{-1} cL_n + [1-\lambda w]^{-1} [x'\beta + wx'\beta] + [1-\lambda w]^{-1} \varepsilon$$

Among them, Y is a $N \times 1$ dimension vector of the ecological efficiency of the interpreted variable area, c is a constant, L_n is an $N \times 1$ dimensional vector with 1 element, x' is a data matrix of $N \times K$ columns, including K column explanatory variables, and $\beta_{K \times 1}$ is the corresponding coefficient, ε is the error term.

The partial differential of the K -th explanatory variable of the above formula at time t can be written as:

$$\begin{aligned}
 \left[\frac{\partial Y_i}{\partial x_{1t}} \quad \dots \quad \frac{\partial Y_i}{\partial x_{Nt}} \right]_t &= \begin{bmatrix} \frac{\partial Y_1}{\partial x_{1K}} & \dots & \frac{\partial Y_1}{\partial x_{NK}} \\ \vdots & \ddots & \vdots \\ \frac{\partial Y_N}{\partial x_{1K}} & \dots & \frac{\partial Y_N}{\partial x_{NK}} \end{bmatrix}_t \\
 &= [1-\lambda w]^{-1} \begin{bmatrix} \beta_k & w_{12}\alpha_k & \dots & w_{1N}\alpha_k \\ w_{21}\alpha_k & \beta_k & \dots & w_{2N}\alpha_k \\ \vdots & \vdots & \ddots & \vdots \\ w_{N1}\alpha_k & w_{N2}\alpha_k & \dots & \beta_k \end{bmatrix}_t
 \end{aligned}$$

In the above formula, β_k is the direct effect corresponding to the explanatory variable. The mean of the elements other than the main diagonal is the indirect effect of the explanatory

variable. The total effect can be obtained from the sum of the direct effect and the indirect effect.

Source of sample data

The data of the control variables selected are derived from China Statistical Yearbook, China Environmental Statistics Yearbook, and China Land and Resources Statistics Yearbook. Because there are many missing data in Tibet, this section needs to be based on the empirical results mentioned above; Tibet is not included in the research analysis below.

Inspection of panel data

Inspection of panel unit root

In order to ensure the stability of panel data to avoid the occurrence of pseudo-regression or pseudo-related between unit root variables, it is necessary to test whether the panel data has a unit root and solve the problems caused by the unit root before the empirical analysis. The inspection methods of the panel unit root mainly include the LLC test, HT test, Breitung test, Hadri test, IPS test, and Fisher-type test. According to different assumptions about the autoregressive coefficients of panel units, the unit root inspection can be divided into two categories, of which the first four tests are applicable to the case of “same root”. The latter two tests are applicable to the case of “different root”, where only the original assumption of the Hadri test is that all panel units are stable. Based on a comprehensive consideration of the applicable asymptotic theory of the cross-sectional dimension and the time dimension, and considering both types of testing methods, stata 15.1 is used to perform the LLC test, Fisher-ADF test, and IPS test on each variable.

The panel unit root test results are shown in Table 6. All three test methods rejected the null hypothesis that there is no unit root in regional ecological efficiency. Therefore, in order to ensure the stability of all variables to do a first-order difference, continue the above test. It can be seen from the results that all variables after the first-order difference rejected the unit hypothesis at a significant level of 5%. Since the economic meaning of the variable after the difference is not the same as the original sequence, if the original variable is continued to be empirically analyzed, it is necessary to examine whether the unit root sequence has a common random trend. It is initially assumed that there is a cointegration relationship between the linear combinations of the variables. The panel co-integration test is performed next.

Panel co-integration test

Throughout the existing panel co-integration test methods, it can be broadly divided into two categories: one is the residual-

Table 6 Panel unit root test for each variable

	Horizontal value			First-order difference		
	LLC	Fisher-ADF	IPS	LLC	Fisher-ADF	IPS
reescore	17.037 3	− 4.844 2	12.719 9	− 3.951 9***	4.045 5***	− 4.249 2***
tescore	− 6.580 5***	2.608 2***	− 3.104 3***	− 9.433 0***	6.901 1***	− 8.308 7***
lnul	1.519 8	40.940 1***	− 2.740 4***	− 20.462 4***	87.851 7***	− 16.179 9***
lnl	− 1.836 2**	1.025 7	− 3.167 2***	− 26.510 7***	4.130 1***	− 18.262 4***
lner	− 3.120 6***	3.735 5***	− 2.274 5**	− 9.922 9***	1.778 9**	− 6.438 0***
lnip	− 4.252 0***	− 1.275 1	− 1.736 8**	− 9.604 2***	2.000 4***	− 6.142 3***
lnicd	− 9.184 0***	0.976 0	− 3.708 3***	− 12.473 0***	6.784 1***	− 10.308 7***

*, **, *** indicate the significance level of 10%, 5%, and 1%, respectively, the same below. 2. Intercept term is included in the unit root test of all the above variables

based panel data cointegration test represented by the Kao test and the Pedroni test, and the other is the test of panel-based vector error correction model developed on the basis of Johansen trace test. Using stata15.1 to carry out Kao test and Pedroni test on the variables after the difference, the results shown in Table 7 are obtained. From the results, there is a significant co-integration relationship between the level of tourism economic development, the level of urbanization, the level of technology, environmental regulation, the openness of investment and the intensity of industrial pollution control. On this basis, the regression analysis of the empirical model can obtain more accurate results.

Spatial autocorrelation test

According to the “first law of geography”, it can be known that the strength of the relationship between things is usually affected by the distance between them, and regional ecological efficiency belongs to regional variables. Therefore, before using the spatial panel measurement model to measure the spatial effect of the impact of tourism economic development on regional ecological efficiency, it should be verified whether the regional ecological efficiency has spatial autocorrelation. The form of spatial weight matrix mainly includes

geographical neighbor weight matrix (0-1 matrix), geographical distance weight matrix, economic distance weight matrix, and social network weight matrix. According to the differences in the nature of the variables and research purposes, selecting the appropriate weight matrix can effectively avoid statistical deviations. For example, Lin et al. (2005) compared the geographic adjacency weight matrix, introduced economic distance into the spatial weight matrix, and found that the economic distance weight matrix can better fit the regional economic development situation of China. Regional ecological efficiency takes into account the coordinated development of the economy and environment, which is closely related to the geographical location and economic development of the region. Therefore, in this paper, we measure the spatial dependence of regional ecological efficiency and its aggregation effects using a binary spatial weight matrix, an inverse distance spatial weight matrix based on longitude and latitude distance measurements, and an economic distance weight matrix based on the average GDP per capita from 2002 to 2016.

To investigate the aggregation of the entire spatial sequence, the global Moran's I is usually used. Table 8 lists the global Moran's I calculated using three weight matrices. Overall, the Moran's I of ecological efficiency was positive

Table 7 Test results of the development level of tourism economy in 30 provinces and cities in China

Statistic name	Statistic value	p value	Test result	
Kao	Modified Dickey-Fuller t	6.469 9	0.000	Reject
	Dickey-Fuller t	11.168 2	0.000	Reject
	Augmented Dickey-Fuller t	8.653 6	0.000	Reject
	Unadjusted Dickey-Fuller t	6.283 1	0.000	Reject
	Unadjusted modified Dickey-Fuller t	8.917 1	0.000	Reject
Pedroni	Modified Phillips-Perron t	8.139 0	0.000	Reject
	Phillips-Perron t	− 3.030 2	0.001	Reject
	Augmented Dickey-Fuller t	− 3.088 6	0.001	Reject

Table 8 Statistics of global Moran’s *I* for regional ecological efficiency

Year	Adjacency weight matrix	Geographic distance weight matrix <i>z</i>	Economic distance weight matrix			
	Moran’s <i>I</i>		Moran’s <i>I</i>	<i>z</i>	Moran’s <i>I</i>	<i>z</i>
2002	0.415***	4.009	0.115	1.132	0.028	0.790
2003	0.453***	4.064	0.158*	1.415	0.069	1.274
2004	0.466***	4.265	0.226**	1.887	0.103**	1.663
2005	0.490***	4.414	0.289***	2.318	0.134**	2.016
2006	0.500***	4.418	0.358***	2.766	0.171***	2.418
2007	0.486***	4.259	0.413***	3.122	0.205***	2.785
2008	0.475***	4.165	0.460***	3.452	0.219***	2.947
2009	0.470***	4.112	0.497***	3.701	0.226***	3.023
2010	0.460***	4.028	0.481***	3.585	0.204***	2.762
2011	0.461***	4.053	0.593***	4.380	0.259***	3.417
2012	0.451***	3.970	0.587***	4.336	0.267***	3.502
2013	0.407***	3.805	0.720***	5.533	0.243***	3.401
2014	0.449***	4.119	0.751***	5.697	0.268***	3.664
2015	0.462***	4.159	0.755***	5.640	0.300***	3.984
2016	0.439***	3.920	0.768***	5.669	0.295***	3.881

from 2004 to 2016, and passed a significant level test of 5%, basically indicating that there is significant spatial autocorrelation in regional ecological efficiency. It is worth noting that, unlike the results of the adjacent weight matrix, the Moran’s *I* of 2002 obtained by using the geographic distance weight matrix and the Moran’s *I* of 2002 and 2003 obtained by economic distance rejected the original hypothesis. However, this does not mean that the self-relevance of regional eco-efficiency spaces in the past two years does not exist. The spatial correlation only exists in some areas or the areas where positive correlation and negative correlation cancel each other out, which may lead to insignificant results (Zhao et al. 2014). From the perspective of time, the Moran’s *I* derived from the geographic distance weight and the economic distance weight has a gradually increasing trend, which indicates that with China’s economic development into the “new normal”, the flow of factors between provinces and cities and the high pressure formed by the advantage areas to promote the optimization of resource allocation and upgrading industrial structure in backward areas. Presenting the situation of the development of the surrounding area driven by some areas in the “highland” of ecological efficiency, the gradual enhancement of spatial dependence and the increasingly obvious phenomenon of aggregation has become an objective fact.

Recognition of spatial panel models

As a preliminary test of spatial effect, Moran’s *I* shows that it is necessary to consider spatial factors when studying the relationship between tourism economic development and

regional ecological efficiency. The traditional panel regression model may cause deviation in regression estimation results by ignoring the existence of spatial effects. The following is to construct the non-spatial panel model for ordinary regression and explain the rationality of building the space panel model through the LM test.

From the object of study, the spatial relationship of ecological efficiency between regions is not limited to the adjacency of geographical locations. Therefore, the definition of a 0-1 weight matrix cannot fully meet the objective distribution characteristics of regional ecological efficiency. Table 9 shows the ordinary panel regression and its corresponding LM test results. The results of LM test based on the geographical distance weight matrix reject the original hypothesis that there is no spatial error or spatial lag effect at a significant level of 1%. The ordinary panel model does not hold the basic assumption that the variables are spatially independent of each other, resulting in the statistical result of regression is no longer an optimal unbiased estimate. Therefore, incorporating spatial factors into the panel model is a better choice. In addition, from the statistics of the LM test results, the LM Error statistics (175.012, 110.464) are significantly larger than the LM Lag statistics (79.091, 14.542), indicating that the spatial error model has a better fit than the spatial lag model.

In order to modify the classic linear model by incorporating spatial influence factors, we first need to examine the more general SPDM. According to the test results in Table 10, Wald and LR statistics believe that the SPDM cannot be simplified to SPLM or SPEM at a significant level of 1%. The spatial panel model is divided into a random effect model and a fixed

Table 9 Results of ordinary panel regression

Variable	Estimated value	<i>t</i> value	<i>p</i> value
tescore	1.601 9	2.09	0.037
(tescore) ²	− 1.983 3	− 2.70	0.007
lnicd	0.009 0	1.07	0.283
lner	− 0.451 9	− 6.69	0.000
(lner) ²	0.019 9	6.03	0.000
lnl	0.040 3	9.07	0.000
lnul	− 2.908 2	− 8.91	0.000
(lnul) ²	0.409 5	9.47	0.000
lnip	0.032 7	2.60	0.010
Adjusted R ²	0.623 9		
LM test no spatial error		175.012	0.000
Robust LM test no spatial error		110.464	0.000
LM test no spatial lag		79.091	0.000
Robust LM test no spatial lag		14.542	0.000

effect according to the differences in the residual component decomposition. John and Sons (2001) believe that the statistical results estimated using the fixed-effect model are more reliable when the investigated spatial section belongs to the full sample. The specific judgment of which effect model should be used depends on the test results of Hausman. The Hausman statistic in Table 10 is a positive number of 99.41, and through the 1% significance test, that is, the null hypothesis is strongly rejected, indicating that a fixed-effect model should be selected for analysis.

Analysis of empirical results

Table 11 shows the parameter estimates and significant levels obtained by the SPDM based on the two-weight ingress binary matrices under different fixed-effect conditions. From the test results, whether it is the geographical distance weight matrix or the economic distance weight matrix, the Log-likelihood of the double fixed effect is larger than the spatial fixed effect, but the corresponding adjustment of the fit coefficient (*R*-squared) is lower. Therefore, this paper selects the spatial fixed effect model with a high fit coefficient to

Table 10 Test results of the space panel metrology model

Test methods	Statistics	Probability
Wald-spatial lag	32.37	0.000 2
LR-spatial lag	31.42	0.000 0
Wald-spatial error	50.80	0.000 0
LR-spatial error	33.16	0.000 0
Hausman	99.41	0.000 0

characterize the spatial effect of tourism economic development on regional ecological efficiency.

Combined with the results of Tables 8 and 11, the following conclusions can be obtained:

First, unlike the previous test results, the traditional panel regression model makes the statistical results biased by neglecting the spatial interaction between variables. Compared with the statistical results under the spatial fixed effect of model A in Table 11, the specific performance is that the impact of the development of the tourism economy, the level of urbanization and the intensity of industrial pollution control on regional ecological efficiency is underestimated. Overestimating the impact of environmental regulations, technological levels and investment openness on regional ecological efficiency. Similarly, compared with the results of the spatial fixed effects of Model B, each variable shows a biased estimate of regional ecological efficiency in different degrees and directions.

Second, on the whole, the regression results are in line with the assumptions mentioned above. In the estimation results of the spatial fixed effects of Model A, except for the first-order coefficient of the level of tourism economic development, which passed the significance test of 10%, the other variables passed the significance test at the level of 5%. In the estimation results of space fixed effects of model B, the impact of industrial pollution control on regional ecological efficiency is no longer significant, and the remaining variables are significant at the level of 10%. This shows that regional ecological efficiency is significantly affected by the development of tourism economy, environmental regulations, urbanization level, technological level, and investment openness.

Third, the influence of tourism economic development on regional ecological efficiency shows a relatively obvious Kuznets effect. The result of the panel model based on different weight matrix is consistent, that is, the first-time item coefficient of tourism economic development is significantly positive, while the coefficient of the secondary square item is significantly negative. The influence of tourism economic development on regional ecological efficiency follows the law of “increase first, decrease later”. With the further transformation and development of the tourism economy, its impact on ecological efficiency should show positive significance. However, the empirical results are contrary to people’s usual perceptions, the reasons for which, this paper summarizes three aspects. First, the tourism industry has a strong dependence. In the early stage of tourism development, due to the low level of infrastructure and investment in most areas, the impact of industrial construction and tourist flow on the environment is weak, tourism economic development mainly depends on innate resource endowment and industrial-scale expansion. The role of efficiency is simply reflected in the improvement of regional economy through tourism income. Second, the ecological environment reflects the “time inertia”.

Table 11 Estimated results of the SPDM model

Variable	Geographic distance weight matrix(A)			Economic distance weight matrix(B)		
	Spatial fixed	Time fixed	fixed	Spatial fixed	Time fixed	fixed
tescore	1.796 1*	1.741 5**	1.367 9	2.365 3**	2.046 6***	2.015 7**
(tescore) ²	-2.082 6**	-2.005 6***	-1.717 6**	-2.631 0***	-2.513 5***	-2.244 3***
lnicd	-0.015 9**	0.001 8	-0.023 4**	-0.004 8	0.008 0	-0.016 4**
lner	-0.155 0**	-0.412 7***	-0.115 0*	-0.120 8	-0.408 4***	-0.171 1***
(lner) ²	0.008 5**	0.017 8***	0.006 7**	0.006 6*	0.018 3***	0.008 8***
lnl	0.020 7***	0.046 5***	-0.000 5	0.031 1***	0.0483***	-0.015 0
lnul	-3.123 2***	-2.831 8***	-1.735 9***	-2.979 4***	-2.8123***	-1.806 8***
(lnul) ²	0.438 7***	0.391 4***	0.231 9***	0.415 0***	0.394 0**	0.249 9***
lnip	0.026 3**	0.015 6	0.029 3**	0.041 9***	0.023 3	0.022 4*
W*tescore	-110676.5***	-2352.812	-62536.25**	-454.095 7*	116.785 5	-275.232
W* (tescore) ²	89033.19***	1768.171	49111.33**	496.670 8	-117.551 2	333.653 1
W*lnicd	197.801	221.478	437.989 2**	-0.215 1	0.779 5	1.035 6
W*lner	2047.361	-327.944 7	6086.316**	-34.969 8	-92.095 7***	-62.190 7***
W* (lner) ²	-79.303 2	-0.191 6	-283.953 9***	1.427 7	4.222 8***	2.833 7***
W*lnl	-175.583 5*	222.592 4	135.760 1	-2.167 4	-2.636 8***	-0.794 2
W*lnul	-24627.34**	9.211 1	17980.69*	-135.878 6	253.054 5***	115.583 3
W* (lnul) ²	3355.34**	-11.903 0	-2507.769*	22.170 2	-31.845 0***	-14.180 7
W*lnip	461.098 9	108.743 3	756.984 7*	-0.732 8	5.606 0**	1.156 2
λρ	2 744.619***	-2407.119***	-2 807.328***	2 707.706***	-11.999 1**	-18.550 5
R-squared	0.561 9	0.440 3	0.388 3	0.564 5	0.455 2	0.004 1
Log-likelihood	524.305 9	431.812 8	616.912 8	519.168 0	442.903 5	591.576 1

After entering the environment, industrial pollutants and domestic waste will undergo the process of diffusion, migration, and conversion. The environmental pollution caused by the early stage of tourism development is reflected in the later statistical data. Third, with the promotion of people’s living needs and the development of tourism industry, under the bilateral role of supply and demand, the environmental damage caused by industrial activities and human tourism activities exceed the ecological carrying capacity and self-healing capacity, and the value added of industry is not enough to make up for the environmental costs.

Fourth, the level of urbanization and environmental regulations both play a role of “reducing first and then promoting” to regional ecological efficiency. Models A and B in Table 11 can be seen that the coefficient of quadratic square terms of urbanization is positive (0.438 7; 0.415 0), and the coefficient of a linear term is negative (-3.123 2; 0.0419), thus forming a “U” shape with the regional ecological efficiency, which is consistent with the conclusions of Zheng et al. (2017). Influence of environmental regulation represented by sewage charges on regional ecological efficiency has been the subject of debate in academic circles. Chen (2008) and Chen (2016) believe that the effect of environmental regulation on regional ecological efficiency is not significant based on the evaluation of regional ecological efficiency

and the study of spatial effects. In addition, by constructing empirical models such as VAR, it is not uncommon to find articles with a positive or negative correlation between them. By introducing the secondary square of environmental regulation, this paper draws the same research conclusions as Li et al. (2010) and Luo et al. (2013), and verifies that the environmental regulation and regional ecological efficiency are not a simple linear relationship.

Fifth, there are significant spatial spillover effects of regional ecological efficiency. From the spatial fixed-effect model, it can be seen that the spatial error coefficient ρ is significantly positive. This shows that due to the differences in ecological efficiency between different regions, the effects of “seeing and thinking” and “promoting competitions” are easily formed in the process of economic development and environmental protection between provinces and cities(Huang et al. 2018). The improvement of ecological efficiency in neighboring areas will drive the surrounding regional demonstration and imitation, and strive to narrow the gap.

Decomposition of space spillover effect

Due to the existence of spatial factors, a regional variable will not only have an impact on the ecological efficiency of the

region but may also directly affect the ecological efficiency of other regions or indirectly through the regional ecological efficiency. In view of this, the regression coefficients obtained by the previous spatial panel Durbin model are not the marginal effects of each explanatory variable on the interpreted variable. In order to explore the influence path of each variable in-depth, this paper estimates the direct, indirect, and total effects of each explanatory variable on regional ecological efficiency based on the constructed spatial panel Durbin model that includes spatial fixed effects.

The decomposition results of the space spillover effect are shown in Table 12. Comparing the direct and indirect effects of different variables, we can see that the development of tourism economy has a significant spillover effect on regional ecological efficiency, that is, in the early stage of the development of tourism economy, there is a competitive relationship between the region and the surrounding areas. The absorption of tourism consumption and the transfer of environmental pollution have made the surrounding areas a “tourism vacuum zone” and a “pollution haven” in this area (Hui and Zhao 2017). In the later stage of the development of the tourism economy, the region will promote the development of the tourism economy in the surrounding areas through the spatial penetration of tourism flows and the spatial overflow of tourism knowledge innovation. Due to the lag in environmental reflection and environmental costs mentioned above, the improvement of the region’s ecological efficiency has been suppressed to some extent. The direct effect of industrial pollution control is negative at a significant level of 10%, which fully reflects that the current treatment of environmental pollution is still in the stage of “high input and low efficiency”. Under the two-way pressure of economic performance assessment and pollution control requirements, local governments have difficulty grasping the coordinated development of economic growth and regional ecological environment. The development model of “pollution first, prevention, and control later” will bring huge environmental costs and governance costs. Environmental regulations mainly have a certain impact on the region. The levy of sewage charges is only for the sewage companies in the region, the intensity of environmental regulations also varies according to the environmental protection policies of different regions, so the ecological efficiency of neighboring regions will not be affected by it. Similarly, the impact of technological level on the ecological efficiency of other regions is not significant, however, its direct effect is 0.020 3, which indicates that if the technical level is increased by 1%, it will directly improve the regional ecological efficiency by 0.020 3%. The decomposition results of the impact of urbanization level on regional ecological efficiency indicate that the urbanization process is geographically interlinked, and the ecological efficiency of a certain area will be affected by the urbanization level of this area and other areas. The spatial effect of investment openness shows that the inflow of foreign investment in the region will not only directly promote the improvement of ecological efficiency

Table 12 SPDM spatial spillover effect decomposition

Variable	Direct effect	Indirect effect	Total effect
tescore	1.351 7 (1.29)	− 8.404 9 ^{***} (− 3.23)	− 7.053 1 ^{**} (− 2.37)
(tescore) ²	− 1.746 1 [*] (− 1.86)	6.591 8 ^{***} (2.77)	4.845 6 [*] (1.81)
lnicd	− 0.014 4 [*] (− 1.90)	0.013 4 (0.76)	− 0.000 9 (− 0.05)
lner	− 0.150 5 ^{**} (− 2.08)	0.114 4 (0.48)	− 0.036 1 (− 0.13)
(lner) ²	0.008 4 ^{**} (2.36)	− 0.003 7 (− 0.33)	0.004 7 (0.37)
lnl	0.020 3 ^{***} (3.73)	− 0.010 3 (− 1.32)	0.009 9 (1.42)
lnul	− 3.271 4 ^{***} (− 6.82)	− 2.617 0 ^{***} (− 2.72)	− 5.888 5 ^{***} (− 5.35)
(lnul) ²	0.458 9 ^{***} (7.07)	0.359 6 ^{***} (2.72)	0.818 5 ^{***} (5.42)
lnip	0.029 5 ^{**} (2.27)	0.041 3 [*] (1.66)	0.070 9 ^{***} (2.63)

t statistic values are in brackets below the coefficient

in the region, but also the technology, system, and culture introduced with foreign investment will have a positive spillover effect on neighboring regions through the learning mechanism, connection mechanism, and diffusion mechanism (Appendix Tables 13 and 14).

Research conclusions and policy implications

Using panel data of 30 provinces and cities in China from 2002 to 2016, this paper measures the level of regional ecological efficiency and tourism economic development by using input-oriented super-efficient DEA model and grey correlation analysis under the entropy weight. On this basis, the ordinary panel regression model and the spatial panel Durbin model after considering the spatial influence factors are used to reveal the impact of tourism economic development on regional ecological efficiency and the spatial spillover effect. Draw the following conclusions: (1) From the perspective of input and output, there is a large gap in ecological efficiency in different regions. Although the ecological efficiency of most provinces and cities has improved significantly over time, the overall level is still low. (2) Provinces and cities can be divided into three echelons according to the level of tourism economic development. There are high levels of tourism economic development in the east and west. It can be seen that the tourism market with different regional characteristics and cultural environment meets the diversified consumer demand of modern tourists. (3) There is a significant spatial positive correlation in regional ecological efficiency, and spatial agglomeration

and spatial dependence are gradually increasing. (4) The test results of the ordinary panel model show that the existence of space effect must be fully considered when examining the relationship between the level of tourism economic development and regional ecological efficiency. (5) There is a significant inverted “U” curve relationship between the level of tourism economic development and regional ecological efficiency, that is, the improvement of tourism economic level will promote the improvement of regional ecological efficiency in the short term, when the regional tourism economy develops to a certain extent, the environment pollution inhibits the regional ecological efficiency through the “space path” of industrial interdependence and the “temporal inertia” reflected by the ecological environment. In addition, from the perspective of space spillover, the local ecological efficiency is affected by the level of tourism economic development in the neighboring region, that is, with the evolution of time, the tourism economic development of the neighboring region shows an obvious spillover effect of “first negative, then positive” on the ecological efficiency of the region. (6) The results of the space panel Dubin model under the space fixed effect show that environmental regulation, technical level, urbanization level, and investment openness have a significant impact on regional ecological efficiency in different degrees and directions. Among them, the impact of environmental regulation and urbanization on regional ecological efficiency shows a “U” curve relationship between suppression and promotion. The decomposition results of spatial effect show that urbanization and investment openness have direct effects and spillover effects. The remaining control variables only have an impact on the ecological efficiency of the region, and there is no significant spatial spillover.

From the empirical results and the above research conclusions, the following policy inspirations are mainly obtained:

First, we should release the development potential of the tourism industry and promote the coordinated development of tourism-economy-ecological. Due to the obvious “Kuznets curve” effect of the development of the tourism economy on regional ecological efficiency, the blind development of tourism resources and the lack of tourism management system and legislation have seriously restricted the improvement of regional ecological efficiency. Therefore, in the context of the development of eco-tourism, the country should control the overall strategic direction of the development of the tourism industry and guide the deep integration of tourism and green industries. Local tourism management departments should, according to local conditions, highlight local eco-tourism projects, promote diversification of tourism products, improve tourism facilities, globalize tourist attractions, and build virtual reality systems that can improve the tourism consumer experience based on the development of the fifth-generation communication networks. Enhance the tourists’ awareness of environmental protection through online publicity and education. At the same time, combine theory and practice to gradually improve the tourism management system and related laws, and give full play to the normative role of laws.

Second, we should build a multi-channel tourism information-sharing mechanism to strengthen interregional exchanges and cooperation. The spatial flow of tourism flows and factors of production will have a spillover effect on the ecological efficiency of other regions. Real-time network information communication channels and regular cross-regional dialogue cooperation mechanisms can break the barriers to knowledge and technology caused by spatial distances and policy differences, and enhance the spillover effects of the developed tourism areas on the backward areas. Promote the coordinated development of regional tourism economy, so as to improve the overall level of regional ecological efficiency. At the same time, on the basis of win-win cooperation, regional governments will be conducive to the implementation of advanced development concepts and environmental innovation technologies through the establishment of a comprehensive pilot area for eco-tourism cooperation. And through demonstration, it can effectively promote the surrounding areas to change the development model of the tourism economy and improve the quality of tourism services.

Third, we should vigorously promote the process of new urbanization and rationally control the intensity of environmental regulations. The results show that in order to meet the requirements of different stages of development, China has changed the previous development mode of pursuing high-speed economic growth. The level of urbanization and environmental regulation has a significant positive effect on the improvement of regional ecological efficiency, and the improvement of urbanization level has a spatial spillover effect. Environmental issues that were neglected in the past urbanization process have been improved in the process of new urbanization. The government can promote new urbanization development through various policy measures and economic means, such as continuing to implement the “toilet revolution” and speeding up waste classification in cities across the country promotion. In the aspect of pollution prevention and control, China’s government should reasonably grasp the levy of sewage charges and adopt a differentiated sewage charge policy for traditional industries and emerging industries, so as to accelerate the transformation and upgrading of regional industrial structures.

Fourth, we should control the emission of pollution sources and improve the efficiency of industrial pollution control. Based on the previous empirical results, the “invalidation” and “decreasing returns to scale” of industrial pollution control make a negative linear relationship between the intensity of industrial pollution control and regional ecological efficiency. In this regard, the government should control the emission of pollutants from industrial enterprises from the source. For

the ecological environment pollution that has been caused, it should deploy professionals to survey and evaluate, formulate scientific and reasonable investment plans for pollution control, and strengthen the transparency of the process of capital investment and the supervision of project operation. In addition, on the one hand, the government should implement the corresponding incentive policy for technological innovation, and give full play to the sustained momentum of innovation capacity for capacity improvement and pollution control. On the other hand, while ensuring the development of “infant industries” in the region and avoiding becoming “pollution refuges” in developed regions, the government should pay attention to improve the level of investment openness, so as

to effectively release the technical effect and demonstration effect brought by foreign direct investment, and realize the positive effect of investment opening on regional ecological efficiency.

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Appendix

Table 13 Evaluation results of regional ecological efficiency in 30 provinces and cities in China from 2002 to 2016

Region	Year															
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Beijing	0.246	0.260	0.285	0.326	0.365	0.423	0.470	0.508	0.570	0.555	0.598	0.673	0.719	0.779	1.213	
Tianjin	0.293	0.309	0.319	0.306	0.340	0.381	0.432	0.493	0.556	0.601	0.645	1.001	1.011	1.002	1.335	
Hebei	0.163	0.173	0.176	0.18999	0.204	0.224	0.243	0.253	0.324	0.303	0.325	0.332	0.362	0.335	0.427	
Shanxi	0.105	0.106	0.120	0.134	0.138	0.151	0.160	0.169	0.196	0.203	0.202	0.213	0.215	0.199	0.241	
Inner Mongolia	0.111	0.124	0.140	0.151	0.167	0.190	0.206	0.226	0.238	0.233	0.246	0.258	0.263	0.275	0.364	
Liaoning	0.141	0.155	0.168	0.190	0.206	0.203	0.231	0.252	0.290	0.288	0.307	0.341	0.338	0.338	0.438	
Jilin	0.140	0.157	0.154	0.159	0.175	0.194	0.211	0.226	0.249	0.252	0.282	0.303	0.309	0.316	0.447	
Heilongjiang	0.160	0.167	0.186	0.197	0.210	0.229	0.247	0.267	0.296	0.282	0.291	0.321	0.343	0.372	0.446	
Shanghai	0.311	0.331	0.329	0.344	0.371	0.419	0.450	0.483	0.551	0.621	0.681	0.739	0.756	0.764	1.156	
Jiangsu	0.249	0.265	0.264	0.259	0.277	0.311	0.339	0.369	0.412	0.405	0.448	0.476	0.533	0.585	0.734	
Zhejiang	0.272	0.284	0.298	0.312	0.330	0.361	0.391	0.413	0.467	0.434	0.479	0.498	0.520	0.543	0.693	
Anhui	0.153	0.163	0.174	0.178	0.190	0.208	0.225	0.243	0.274	0.259	0.274	0.294	0.301	0.278	0.385	
Fujian	0.316	0.306	0.318	0.316	0.323	0.356	0.378	0.401	0.442	0.418	0.434	0.482	0.517	0.543	1.007	
Jiangxi	0.178	0.170	0.172	0.176	0.182	0.196	0.217	0.235	0.271	0.235	0.271	0.247	0.268	0.281	0.289	
Shandong	0.222	0.228	0.245	0.256	0.272	0.303	0.330	0.361	0.454	0.453	0.518	0.598	0.620	0.588	0.846	
Henan	0.189	0.191	0.195	0.202	0.213	0.232	0.251	0.263	0.314	0.304	0.320	0.355	0.358	0.356	0.487	
Hubei	0.174	0.180	0.191	0.203	0.221	0.248	0.259	0.281	0.321	0.305	0.327	0.363	0.370	0.383	0.501	
Hunan	0.183	0.178	0.176	0.183	0.199	0.214	0.234	0.256	0.290	0.284	0.309	0.337	0.351	0.372	0.500	
Guangdong	0.304	0.308	0.312	0.315	0.336	0.350	0.359	0.392	0.433	0.439	0.464	0.501	0.540	0.603	0.754	
Guangxi	0.148	0.144	0.143	0.143	0.157	0.164	0.177	0.194	0.225	0.244	0.259	0.283	0.289	0.290	0.355	
Hainan	0.527	0.506	0.489	0.480	0.479	0.498	0.534	0.565	0.639	0.481	0.493	0.516	0.496	0.522	0.660	
Chongqing	0.181	0.176	0.176	0.171	0.185	0.200	0.209	0.223	0.254	0.259	0.287	0.319	0.334	0.360	0.458	
Sichuan	0.154	0.150	0.156	0.166	0.186	0.205	0.224	0.249	0.283	0.299	0.330	0.356	0.345	0.349	0.410	
Guizhou	0.118	0.115	0.127	0.128	0.133	0.149	0.163	0.162	0.199	0.193	0.192	0.202	0.209	0.200	0.259	
Yunnan	0.187	0.181	0.180	0.174	0.175	0.185	0.196	0.211	0.234	0.201	0.217	0.237	0.250	0.256	0.308	
Shanxi	0.139	0.144	0.149	0.156	0.165	0.179	0.202	0.202	0.227	0.297	0.272	0.289	0.293	0.288	0.363	
Gansu	0.125	0.119	0.126	0.136	0.143	0.157	0.162	0.170	0.190	0.180	0.195	0.205	0.209	0.206	0.264	
Qinghai	0.275	0.272	0.243	0.211	0.219	0.242	0.273	0.293	0.353	0.340	0.373	0.320	0.323	0.290	0.325	
Ningxia	0.138	0.116	0.113	0.097	0.091	0.085	0.095	0.097	0.122	0.097	0.107	0.130	0.118	0.122	0.141	
Xinjiang	0.146	0.144	0.145	0.150	0.151	0.158	0.164	0.166	0.181	0.174	0.168	0.176	0.179	0.184	0.219	

Table 14 Evaluation results of tourism economic development levels in 30 provinces and cities in China from 2002 to 2016

Region	Year														
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Beijing	0.788	0.658	0.748	0.726	0.757	0.681	0.634	0.583	0.638	0.554	0.619	0.631	0.627	0.564	0.508
Tianjin	0.408	0.401	0.405	0.408	0.409	0.398	0.401	0.398	0.395	0.401	0.403	0.402	0.405	0.397	0.399
Hebei	0.403	0.389	0.391	0.396	0.389	0.386	0.382	0.382	0.388	0.390	0.390	0.388	0.389	0.389	0.400
Shanxi	0.395	0.385	0.395	0.404	0.401	0.400	0.399	0.392	0.390	0.394	0.393	0.388	0.393	0.399	0.402
Inner Mongolia	0.470	0.456	0.468	0.475	0.461	0.469	0.476	0.490	0.501	0.508	0.516	0.512	0.510	0.518	0.521
Liaoning	0.411	0.403	0.407	0.410	0.406	0.411	0.423	0.420	0.414	0.416	0.416	0.415	0.416	0.404	0.400
Jilin	0.410	0.401	0.402	0.405	0.402	0.405	0.411	0.406	0.400	0.396	0.399	0.392	0.392	0.393	0.396
Heilongjiang	0.431	0.426	0.421	0.430	0.431	0.433	0.434	0.423	0.410	0.408	0.407	0.396	0.397	0.396	0.394
Shanghai	0.523	0.507	0.537	0.510	0.484	0.513	0.492	0.488	0.528	0.512	0.515	0.560	0.536	0.589	0.602
Jiangsu	0.460	0.443	0.463	0.476	0.473	0.484	0.488	0.484	0.483	0.492	0.481	0.473	0.470	0.471	0.481
Zhejiang	0.461	0.433	0.448	0.457	0.444	0.449	0.445	0.444	0.446	0.454	0.439	0.432	0.436	0.434	0.418
Anhui	0.377	0.372	0.378	0.382	0.378	0.381	0.384	0.382	0.387	0.396	0.396	0.386	0.386	0.391	0.397
Fujian	0.395	0.394	0.399	0.408	0.397	0.398	0.402	0.405	0.408	0.420	0.418	0.423	0.425	0.433	0.444
Jiangxi	0.381	0.374	0.376	0.381	0.379	0.376	0.382	0.381	0.378	0.391	0.384	0.382	0.387	0.389	0.392
Shandong	0.387	0.382	0.391	0.398	0.404	0.406	0.414	0.417	0.421	0.425	0.423	0.417	0.415	0.416	0.415
Henan	0.382	0.374	0.389	0.396	0.393	0.394	0.399	0.398	0.397	0.397	0.391	0.386	0.386	0.384	0.389
Hubei	0.398	0.385	0.388	0.390	0.389	0.388	0.386	0.390	0.399	0.403	0.408	0.406	0.411	0.408	0.406
Hunan	0.382	0.382	0.386	0.390	0.390	0.391	0.390	0.401	0.409	0.425	0.423	0.411	0.412	0.404	0.417
Guangdong	0.620	0.549	0.590	0.507	0.487	0.508	0.479	0.484	0.489	0.507	0.483	0.490	0.492	0.481	0.479
Guangxi	0.394	0.385	0.392	0.396	0.394	0.400	0.391	0.396	0.395	0.402	0.400	0.394	0.397	0.390	0.398
Hainan	0.436	0.443	0.454	0.424	0.430	0.435	0.434	0.420	0.414	0.417	0.415	0.409	0.418	0.416	0.442
Chongqing	0.421	0.397	0.402	0.410	0.414	0.400	0.393	0.402	0.407	0.429	0.429	0.430	0.433	0.421	0.408
Sichuan	0.379	0.387	0.395	0.402	0.394	0.402	0.384	0.522	0.419	0.540	0.453	0.425	0.418	0.419	0.424
Guizhou	0.379	0.377	0.378	0.382	0.391	0.379	0.379	0.380	0.380	0.382	0.386	0.386	0.387	0.391	0.403
Yunnan	0.417	0.401	0.418	0.435	0.432	0.442	0.433	0.442	0.406	0.418	0.422	0.422	0.421	0.397	0.399
Shanxi	0.391	0.382	0.387	0.389	0.385	0.386	0.379	0.389	0.401	0.413	0.406	0.401	0.403	0.407	0.403
Gansu	0.375	0.369	0.388	0.385	0.385	0.377	0.379	0.377	0.378	0.375	0.377	0.375	0.381	0.382	0.382
Qinghai	0.428	0.423	0.443	0.432	0.491	0.496	0.508	0.479	0.472	0.475	0.465	0.447	0.471	0.467	0.454
Ningxia	0.391	0.390	0.389	0.392	0.392	0.392	0.395	0.393	0.422	0.417	0.418	0.415	0.413	0.408	0.403
Xinjiang	0.427	0.422	0.422	0.417	0.417	0.414	0.408	0.405	0.416	0.419	0.413	0.412	0.417	0.415	0.413

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