Analysis of economic efficiency and eco-efficiency of Chinese star hotels based on SBM model

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Abstract. Star hotels, as the core sector of China's tourism development, the improvement of their economic efficiency is an important way for the tourism industry to operate well. On the other hand, improving eco-efficiency can promote star hotels to take more responsibility for the ecological environment and promote the sustainable development of tourism industry. In this paper, the A Slacks-Based Measure model (SBM), as one kind of data envelopment analysis, is used to construct the economic efficiency and eco efficiency input-output system of Chinese star hotels according to the development characteristics of star hotels in China. By collecting the data in 2014 and using the energy balance sheet to calculate the carbon emission, we further calculate the economic efficiency and eco-efficiency level of the star hotels in 30 provinces in China's main land, and further analysis the input-output spatial pattern and development trend of the eco-economic system in China's star hotels through the Getis-Ord Gi index and coupling analysis. It is found that the economic efficiency and ecoefficiency of Chinese star hotels are consistent with their spatial distribution, and they have a significant linear positive correlation. The spatial distribution of the economic efficiency and eco-efficiency of Chinese star hotels is extremely uneven, and there is no spatial agglomeration. Moreover, the high efficiency area has no obvious positive impact on the periphery.

1. Introduction

In the trade of globalization, the competition between Chinese star hotels and the international hotels group is constantly fierce. Star hotel is the main body of the development of China's tourism industry. Its economic efficiency can be more objective and true to reflect the overall development and development potential of the tourism market. In the past ten years, with the promotion of international organizations such as OECD and WBCSD and many scholars, the concept of eco-efficiency has attracted the attention of policymakers [1], researchers and enterprise managers [2], and has been popularized and applied in many fields [3].Huang (2014) pointed out that eco-efficiency is the input output efficiency of a region under the dual constraints of resources and environment [4].

Data envelopment analysis (DEA) has certain advantages in the application of efficiency problems. [5]. The model does not need the unified index unit [6], does not need to clear the function relation, does not need to estimate the parameter [7], also can contain the undesired output index [8], increases the flexibility of the input and output index selection [9], simplifies the measurement process and

ensures the integrity of the original information [10]. DEA has many extended models [11]. The main analysis models used in economic efficiency and eco-efficiency analysis are the traditional CCR and BCC models [12]. Non radial SBM model with relaxed variables in objective function [13], DDF model of directional distance function [14], Super efficiency model [15] and so on. This study uses the SBM model, which has the attributes of free dimension and variable unit [16], which can be weighted into input-output variables [17], and can also increase undesired output [18]. It is very suitable for evaluating the eco-efficiency of star hotels.

With the increasing global climate change, the research on carbon emission has become a hot topic in recent years. Taking carbon emissions as the undesired ecological environment index in the input-output eco economic system of star hotels, the eco-efficiency level of star hotels can be further analyzed. It can help to find out the pressure of the star hotels on the ecological environment while achieving economic growth.

Therefore, this paper introduces economic efficiency and eco-efficiency as a tool to measure the economic growth and ecological environment protection of star hotels in China. It analyzes the economic efficiency and eco-efficiency level and spatial pattern of the star hotels in 30 provinces in China's main land in 2014, aiming at expanding the research and application fields of economic efficiency and eco-efficiency, for promoting the green and sustainable development of star hotels.

2. Models and Methods

2.1. Analysis of economic efficiency and eco-efficiency: SBM model

This paper takes 30 provinces in China's main land as the decision units for the evaluation of economic efficiency and ecoefficiency. Each decision unit in the economic efficiency analysis includes input and output vectors, respectively. It is expressed as $x \in R^m$, $y \in R^s$. We definite matrix X, Y as $[X] = [x_1, \cdots, x_n]^T \in R^{m \times n}$, $[Y] = [y_1, \cdots, y_n]^T \in R^{s \times n}$, $X>0$, $Y>0$, and definite production possibility set P as $P = \{(x, y) | x \geq \lambda x, y \leq \lambda Y, \lambda \geq 0\}$.

The basic expression of SBM is [19]:

$$\min P^* = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_{i0}^-}{x_{i0}}}{1 + \frac{1}{s}\sum_{r=1}^{s} \frac{s_r^+}{y_{r0}}} \tag{1}$$

$$St. x_0 = X\lambda + s^- \tag{2}$$

$$y_0 = Y\lambda - s^+ \tag{3}$$

$$\lambda \geq 0, s^- \geq 0, s^+ \geq 0 \tag{4}$$

This study calculates the eco-efficiency of China's star hotels by SBM model constructing a Undesirable outputs. Each decision unit includes three vectors: input, expected output and undesirable output. It is expressed as $x \in R^m, y^g \in R^{s_1}, y^b \in R^{s_2}$. We definite matrix X, Y^g, Y^b as : $[X] = [x_1, \cdots, x_n]^T \in R^{m \times n}$, $[Y^g] = \left[y_1^g, \cdots, y_n^g\right]^T \in R^{s_1 \times n}$ *and* $[Y^b] = \left[y_1^b, \cdots, y_n^b\right]^T \in R^{s_2 \times n}$, $X>0$, $Y^g>0$, $Y^b>0$, and definite production possibility set P as $P = \left\{\left(x, y^g, y^b\right) | x \geq \lambda x, y^g \leq \lambda Y^g, y^b \geq \lambda Y^b, \lambda \geq 0\right\}$.

The SBM-Undesirable model based on variable returns to scale expressed as [19]:

$$P^* = \min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_i^-}{x_{i0}}}{1 + \frac{1}{s_1 + s_2}\left[\sum_{i=1}^{s_1} \frac{s_r^g}{y_{r0}^g} + \sum_{i=1}^{s_2} \frac{s_r^b}{y_{r0}^b}\right]} \tag{5}$$

Where, s represents the slack variable of input and output, λ is a weight vector. The objective function about s^-, s^g, s^b is strictly diminishing, and $0 \le P^* \le 1$. For specific decision making units, if and only if $P^* = 1$, and s^-, s^g, s^b are all 0, the ecoefficiency is effective. If $P^*<1$, or s^-, s^g, s^b are not all 0, it shows that the eco-efficiency of decision making units is invalid, and there is the necessity of improving input output variables.

2.2. Spatial pattern analysis: Getis-Ord Gi Index*

Getis-Ord Gi* was proposed by Getis and Ord. It can find sub regions with different attribute values in the study area. It expressed as:

$$G_i^* = \frac{\sum_{j=1}^{n} \varphi_{i,j} x_j - \left(\frac{1}{n}\sum_{j=1}^{n} x_j\right) \times \left(\sum_{j=1}^{n} \varphi_{i,j}\right)}{\sqrt{\frac{\sum_{j=1}^{n} x_j}{n} - \left(\frac{1}{n}\sum_{j=1}^{n} x_j\right)^2} \times \sqrt{\frac{n\sum_{j=1}^{n} \varphi_{i,j}^2 - \left(\sum_{j=1}^{n} \varphi_{i,j}\right)^2}{n-1}}} \tag{6}$$

Where, x_j is the attribute value of factor j, $\varphi_{i,j}$ is the spatial weight between elements i and j, and n is the total number of elements. According to the Gi* index, it can be showed the location of spatial high value (hot spot) or low value (cold spot) elements in space. The hot spots and cold points of the regional economic efficiency and eco-efficiency of the star hotels in China can represent the regions with high concentration of economic efficiency and eco-efficiency and the regions with low concentration.

2.3. Indicators and data

The economic input index of traditional production function mainly includes labor force and capital, output index output value. The input and output indicators of the economic efficiency of the star hotels in China mainly include the traditional labor input and capital input, as well as the number of star hotels which can reflect the overall scale of investment, and the output is income. The eco-efficiency of star hotels is selected from the input-output index of traditional economic efficiency, and the carbon emission level which can reflect the energy consumption and the environmental impact is added as the waste output (Table 1).

Table 1. Input-output indexes of eco-efficiency.

	Name of index	Data sources	Unit
Input	labor	statistical yearbook	persons
	capital investment	statistical yearbook	bln yuan
	number of star-hotels	statistical yearbook	-
Output	income	statistical yearbook	bln yuan
Undesirable output	carbon emissions	calculate	million ton

Through the energy balance of the provinces, the consumption level of all kinds of energy in wholesale and retail and accommodation is converted into standard coal, and the conversion coefficient comes from the energy statistics yearbook of China. Combined with the total value of wholesale and retail sales and the added value of accommodation and catering in 2014, the unit added value standard coal consumption was calculated. According to the carbon emission coefficient of standard coal in IPCC, the added value carbon emission coefficient of wholesale and retail accommodation unit was calculated. Finally, it multiplied with the income of star hotels in all provinces, and calculated the total carbon emission of the star hotels in 2014.

3. Results and Discussion

3.1. Spatial pattern of economic efficiency and eco-efficiency of Chinese star hotels

This study divides the economic efficiency and eco-efficiency (both expressed E) of Chinese star hotels into five levels: inefficiency area (0.00<E<0.40), low efficiency area(0.41<E<0.60), areas to be improved(0.61<E<0.80), relative efficiency area(0.81<E<0.99), high efficiency area(E=1). The results of the analysis are shown in Figure 1. The high efficiency areas of economic efficiency include Beijing, Tianjin, Shanghai, Zhejiang, Fujian, Guangdong, Qinghai, Ningxia, The high efficiency areas of eco-efficiency include Beijing, Tianjin, Shanghai, Jiangsu , Zhejiang, Fujian, Guangdong, Hainan, Qinghai, Ningxia. The spatial distribution pattern of economic efficiency and eco-efficiency is the same.

In a word, the high efficiency area of economic efficiency and eco-efficiency are mainly concentrated in the eastern coastal areas where China's economic development is relatively developed. It further shows that the economic efficiency and eco-efficiency of China's star hotels are positively related to the level of China's economic development. The inefficiency areas of economic efficiency are Hebei, Yunnan, The inefficiency areas of eco-efficiency are Shanxi, Inner Mongolia, Sichuan, Yunnan, Gansu, Xinjiang, Ecological inefficiency is mainly located in the less developed western provinces of China. Good location and high level of economic development are the main constraints on the development of China's star hotels' economic efficiency. The eco-efficiency level of the star hotels in China is low due to the influence of various factors such as the restriction of the eco-technology level and the rationality of the structure of the resource elements in the western region.

3.2. Getis-Ord Gi index analysis of economic efficiency and eco-efficiency of China's star hotels*

According to the above research, the economic efficiency and eco-efficiency of the star hotels in China may have a certain spatial correlation. Therefore, this study introduces the Getis-Ord Gi* index analysis method to further analyze the spatial pattern characteristics of the economic efficiency and eco-efficiency level of star hotels in China.

According to the calculation of Getis-Ord Gi* index, the Getis-Ord Gi* index is divided into 7 categories according to the significant level of spatial positive and negative correlation (figure 2). The economic efficiency is a transitional region with no significant correlation, while Yunnan and Chongqing are the cold spots with 10% eco-efficiency agglomeration significance. The economic growth and environmental impact of China's star hotels have no obvious spatial agglomeration characteristics, showing a certain spatial dispersion. It shows that the imbalance between economic efficiency and eco-efficiency is obvious. And the economic efficiency and eco-efficiency of the better development areas did not achieve the proliferation and spillover effects on the surrounding areas. This is contrary to the trend of the development of hotel industry in other developed countries.

3.3. Spatial coupling analysis of economic efficiency and eco-efficiency of Chinese star hotels

The coupling of economic efficiency (EE) and eco-efficiency (CE) is analysed in this research (figure 3). It is further proved that the economic efficiency and eco-efficiency of the star hotels in 30 provinces in mainland China are basically the same. The study found that the economic efficiency and eco-efficiency were all obvious concave points in Yunnan. The most convexity appeared in 6 provinces in Guangdong, Beijing, Tianjin, Fujian, Zhejiang, Shanghai, and the eco-efficiency and economic efficiency of four provinces of four points were both 1. Through the analysis of economic efficiency and eco-efficiency, the scatter point analysis found that the eco-efficiency and economic efficiency have obvious linear positive correlation, and the contribution rate of unit eco-efficiency to economic efficiency is 0.7852. This study further divides the coupling economic efficiency and eco-efficiency of the star hotels of 30 provinces into 4 types with the relative effective level of 0.8 as the dividing line. Type I is low carbon development type (EE>0.8, CE>0.8), mainly including 6 provinces: Guangdong, Beijing, Tianjin, Fujian, Zhejiang and Shanghai. Type II is high carbon development type (EE>0.8, CE<0.8), there is null.

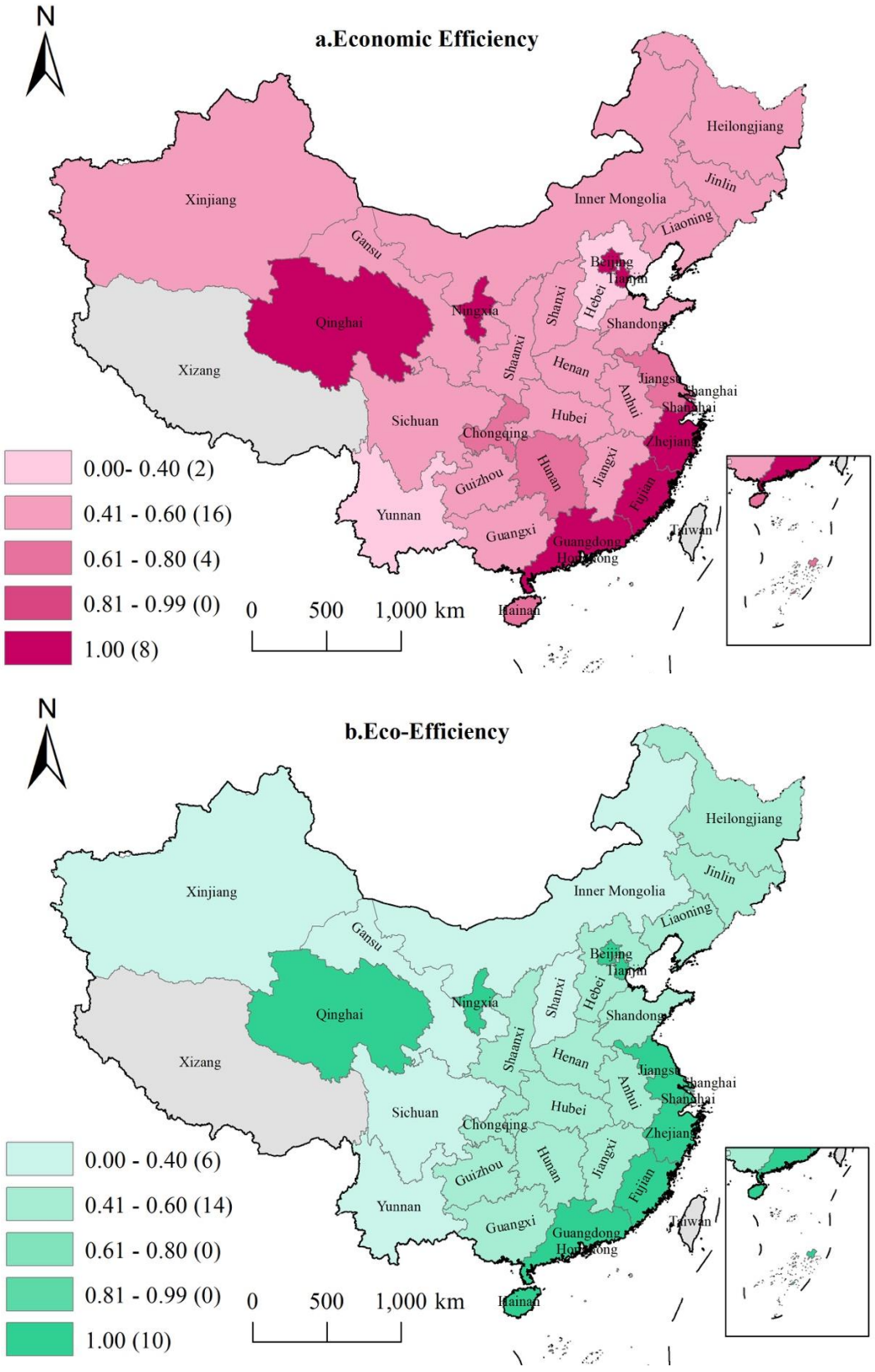

Figure 1. The spatial pattern of economic efficiency and eco-efficiency of star hotels in China

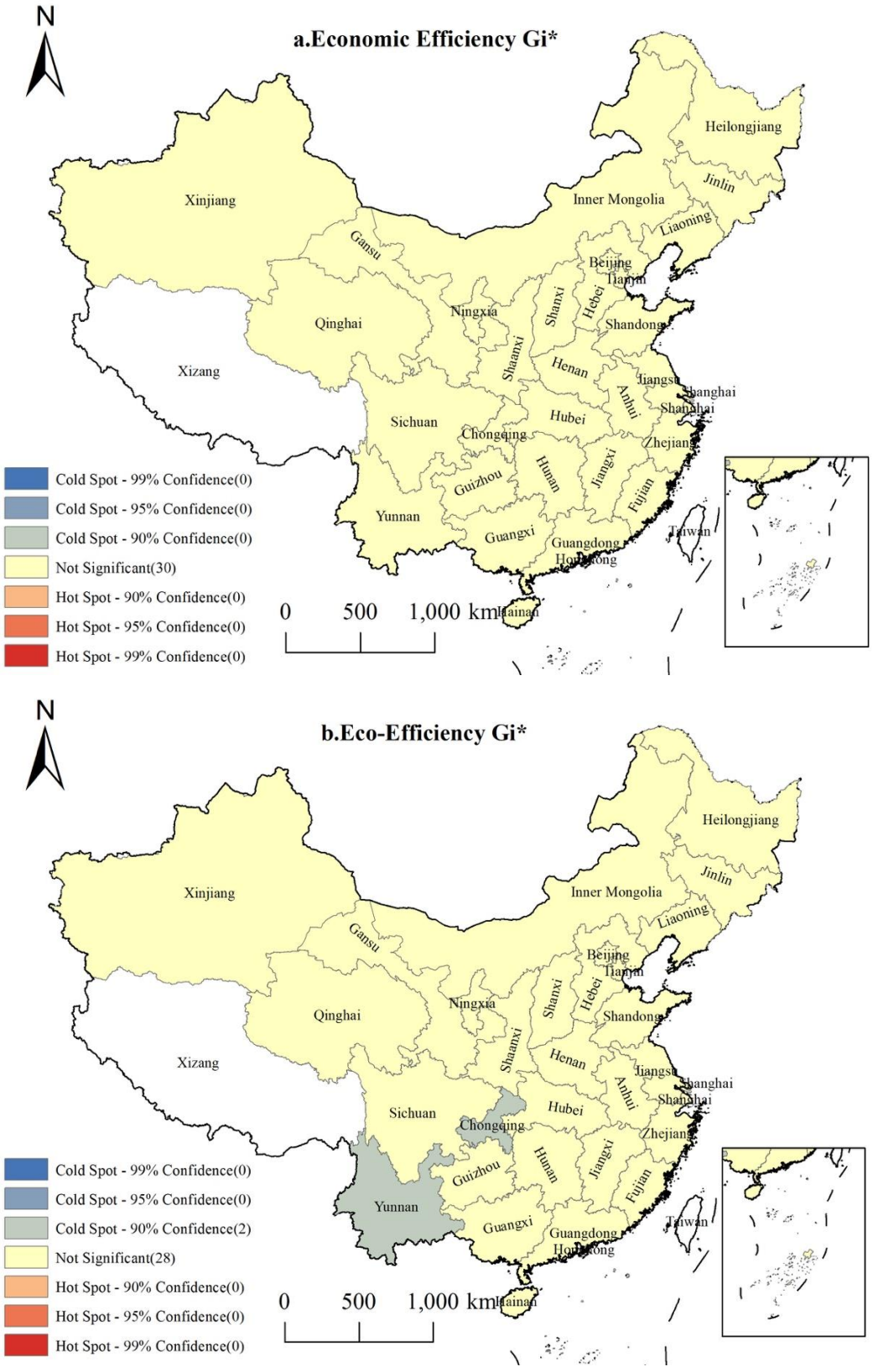

Figure 2. Getis-Ord Gi* index of economic efficiency and eco-efficiency of star hotels in China

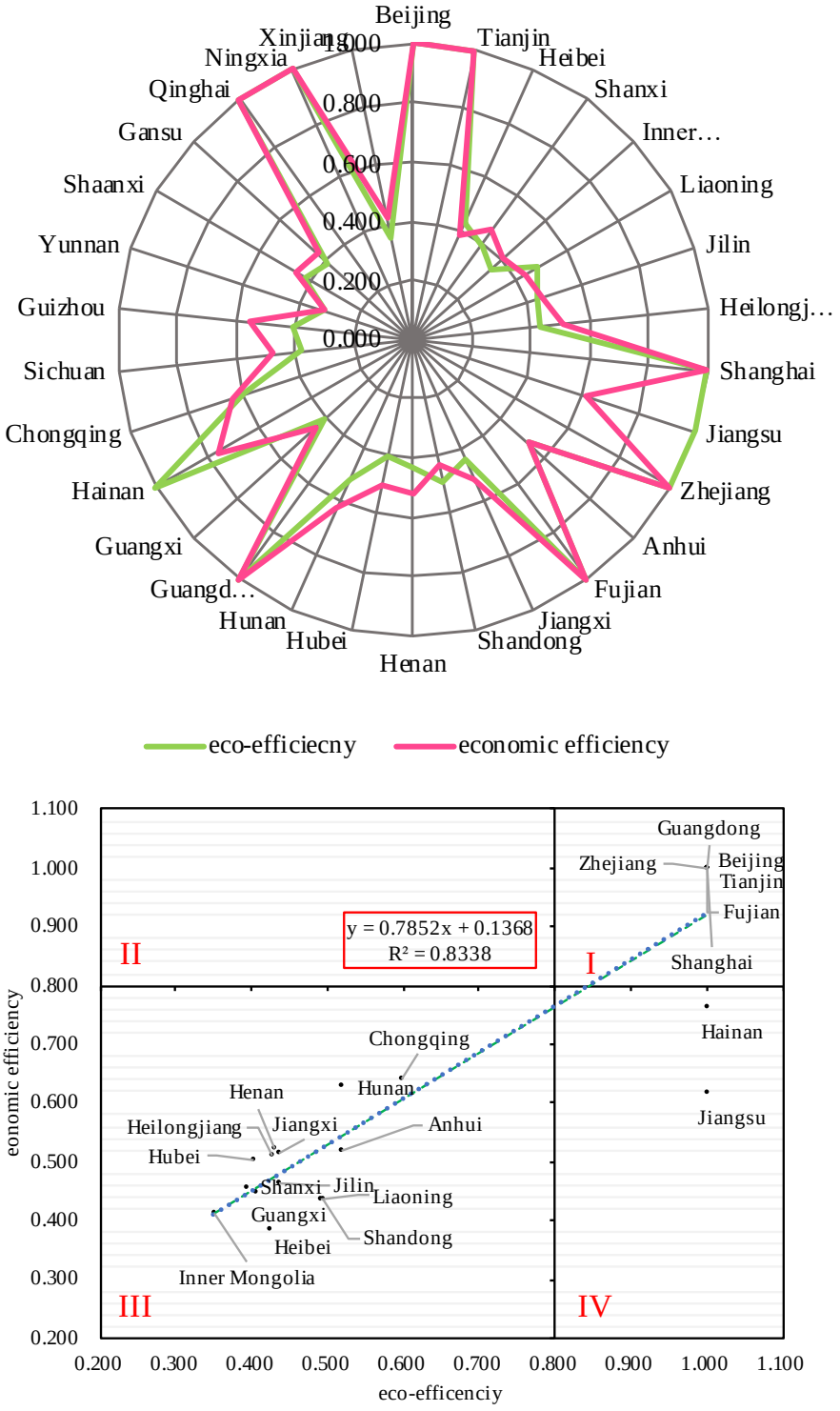

Figure 3. Spatial coupling pattern of eco-efficiency and economic efficiency of star hotels in China

Type III is high carbon and low efficiency (EE<0.8, CE<0.8), most of the development of star hotels in China is this type, and it includes 22 provinces, such as Chongqing, Hunan, Anhui, Jiangxi and so on. Type IV is low carbon and low efficiency (EE<0.8, CE>0.8), mainly including 2 provinces of Hainan and Jiangsu. Type I area should be the demonstration area of green sustainable development

for star hotels in China. It should actively butt with the world famous hotel group, introduce advanced talent and high-end technology of economic innovation and development, adjust the management mode and internal resource allocation structure of star hotels, and improve the additional value of hotel service and products, sustainable development of green and low carbon in star hotels. Type III areas should optimize the input and output redundant variables, optimizing the allocation of resources, improve the capital efficiency, improving the quality of human capital, optimizing the ecological and economic efficiency, and to strive to directly transit to type I area. In order to optimize the area for economic efficiency, type IV areas should optimize the hotel management model, optimize the organization structure, improve the additional value of production and service, and make a steady transition to the type I area.

4. Conclusion

The overall development level of economic efficiency and eco-efficiency of Chinese star hotels is basically the same as that of spatial pattern. Beijing, Tianjin, Shanghai, Zhejiang, Fujian, Guangdong, Qinghai and Ningxia are at the same time at the forefront of the best level of economic efficiency and eco-efficiency. Regions with inefficient eco-efficiency and inefficient economic efficiency mainly concentrated in less developed western China.

According to the coupling analysis of the eco economic efficiency of star hotels in various provinces and regions, the development of star hotels in China is further divided into four types: low carbon development type, high carbon development type, high carbon low efficiency type and low carbon low efficiency type. Low carbon development is mainly concentrated in the developed coastal provinces of eastern China. However, the development of star hotels in most provinces in China is low-carbon and low-efficiency of economic efficiency and eco-efficiency.

The spatial agglomeration characteristics of Chinese star hotels are not significant, and there is no obvious spatial agglomeration characteristics of economic growth and environmental impact. This shows that the imbalance of economic efficiency and eco-efficiency between 30 provinces is obvious. Economic efficiency and eco-efficiency in better developed areas do not achieve the diffusion and spillover effects on the surrounding areas. This is contrary to the trend of the development of hotel industry in other developed countries. The scattered spatial development pattern is not conducive to the agglomeration of industrial elements, and is not conducive to the balanced regional development of star hotels.

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