Spatial-Temporal Differences and Influencing Factors of Tourism Eco-Efficiency in China’s Three Major Urban Agglomerations Based on the Super-EBM Model

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Abstract: On the background of climate change, studying tourism eco-efficiency of cities is of great significance to promote the green development of tourism. Based on the panel data of the three major urban agglomerations in China’s Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei region from 2008 to 2017, this paper constructed an evaluation index system and measured the tourism eco-efficiency of 63 cities by using a hybrid distance model called Super-EBM (epsilon-based measure). We compared the spatial and temporal evolution characteristics of tourism eco-efficiency in the three urban agglomerations. Furthermore, the internal factors influencing tourism eco-efficiency were explored through input–output redundancy, and the external factors were analyzed by a panel regression model. The results indicate that the tourism eco-efficiency of the three urban agglomerations in China generally shows a decreasing-rising-declining trend. Among them, the Yangtze River Delta has the highest eco-efficiency, followed by the Pearl River Delta, and the lowest in the Beijing–Tianjin–Hebei region. Moreover, there is a certain gap within each urban agglomeration. The redundancy input of labor and capital is the main internal cause of low eco-efficiency. Among the external factors, the status of the tourism industry and the level of urbanization have a positive effect on eco-efficiency, while the level of tourism development, technological innovation and investment have a negative impact on it. In the future, we must attach great importance to the development quality and overall benefit value of the tourism industry so as to achieve green and balanced development of the three major urban agglomerations in eastern China. Based on the above conclusions, this paper puts forward targeted policy implications to improve the tourism eco-efficiency of cities.

Keywords: tourism eco-efficiency; Super-EBM model; urban agglomerations; influencing factors

1. Introduction

Global climate change, with climate warming as the main feature, is increasingly becoming a serious challenge for mankind [1]. Tourism was once called a “smoke-free industry”. As one of the world’s largest and fastest-growing economic sectors, its development has received much attention from governments. However, as the scale of the tourism industry continues to grow, the ecological and environmental problems caused by it have increasingly received widespread attention from governments and international communities. From the perspective of carbon emissions, tourism is a
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healthy rather than low-carbon lifestyle [2], and tourism carbon emissions are an important driving force for tourism environmental issues and climate change [3], and an important indicator reflecting the impact from the development of tourism on environmental changes [4]. At the same time of realizing economic growth, controlling and reducing greenhouse gas emissions and realizing the “low-carbon” transformation of socio-economic development mode have become an inevitable choice to maintain global ecological security and achieve sustainable development. The concept of eco-efficiency was first proposed by Schaltegger and Sturm in 1990, and its basic idea is to obtain the maximum economic value with the minimum resource input and environmental cost [5]. It is an effective tool to evaluate the degree of “low carbonization” and the state of sustainable development of regional economy, and has increasingly become an important research frontier [6].

The three major urban agglomerations of the Yangtze River Delta, the Pearl River Delta, and the Beijing–Tianjin–Hebei region are the main regional units to promote China’s urbanization process and economic transformation and upgrading. They are the leading areas for China’s regional integration and strategic core areas for economic development. However, the rapid development of the social economy of urban agglomerations has also brought increasingly serious resource and environmental problems, and its green, balanced and sustainable development is a major issue that the government and theoretical circles need to solve urgently. In recent years, driven by the two-wheel drive of demand and investment, the tourism economy of the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei region has grown rapidly. According to the statistical yearbooks of various provinces and cities, the three major urban agglomerations achieved tourism revenues of 3.55 trillion, 0.91 trillion, and 1.75 trillion yuan, respectively, in 2018. However, the impact of tourism activities on the ecological environment of modern urban agglomerations is further highlighted. Under the high-intensity development mode, there is an imbalance between the growth of tourism and the protection of ecological environment, which has a significant negative impact on the environmental sustainability of urban agglomerations [7,8]. Tourism eco-efficiency, as a key indicator of sustainable development of the ecological environment, can comprehensively reflect the coordinated development level of urban economic activities and the ecological environment. The tourism industry of urban agglomerations must emphasize the impact of short-term and long-term development on the environment [9], as well as the balance between tourism resources and ecological environment [10], and pay more attention to the quality of tourism development. Besides, different regions often have differences in tourism eco-efficiency due to such factors such as geographic environment, industrial development models, and tourist behavior preferences. Therefore, in-depth exploration of the tourism eco-efficiency in China’s major urban agglomerations, and further comparison of the spatial-temporal differences in tourism eco-efficiency between urban agglomerations and formation mechanism are the logical starting points for exploring the green and balanced sustainable development of cities. It can not only help us better coordinate the relationship between regional economic development and ecological environment and formulate policies according to local conditions, but also provide new ideas for urban green eco-tourism and sustainable industrial development and accelerate the transformation and upgrading of the economic industry and the upgrading of the development level of urban agglomerations through the construction of new methods and models. Furthermore, it provides reliable theoretical guidance and policy recommendations for the realization of sustainable development of “innovation, coordination, green, opening and sharing”. On the other hand, as the world’s second largest economy and manufacturing power, China’s three major urban agglomerations, the Yangtze River Delta, the Pearl River Delta, and the Beijing–Tianjin–Hebei region, are economic engines of China and even Asia. Paying attention to the spatiotemporal evolution characteristics and dynamic mechanism of their tourism eco-efficiency can not only provide experience for the sustainable development of urban tourism in other countries, but also provide Chinese cases, experiences and lessons for the industrial transformation and upgrading and green balanced development of world urban agglomerations, which has important international exemplary significance.
The core concept of tourism eco-efficiency stems from eco-efficiency, which refers to the ratio of the added value generated by social and economic activities to the damage to the environment, and emphasizes the consideration of ecological environmental impact of human activities and economic and social development benefits. In 1992, the World Business Council for Sustainable Development (WBCSD) defined the concept of eco-efficiency in its publication “Changing course: a global business perspective on development and the environment”, which has gained wide acceptance and recognition worldwide [11]. Moreover, many research institutions and international organizations further expanded the connotation of eco-efficiency. The organization for economic cooperation and development defined eco-efficiency as “the efficiency of using ecological resources to meet human needs” [12], and the United Nations conference on trade and development interpreted it as “increasing shareholder value and reducing damage to the environment” [13]. Although there are subtle differences in the concept expression, they are consistent in the core concept of balancing ecological benefits and economic benefits to obtain the maximum economic output. Since then, scholars at home and abroad have actively carried out empirical studies on eco-efficiency, and achieved rich results in the fields of enterprise [14,15], industry [16–19], and regional system [20–23] eco-efficiency evaluation.

The eco-environmental problems caused by tourism have subverted the beautiful assumption that tourism is a “smokeless industry” and have aroused people’s attention to its economic benefits and the impact of the ecological environment. In 1990, the draft “Sustainable Tourism Development Action Strategy” clearly put forward the concept of “sustainable tourism”, and pointed out that the tourism industry also needs to carefully handle the relationship between the present and the future, foreign tourists and local residents, tourism needs and resource protection. Scholars put forward the concept of tourism eco-efficiency from the perspective of sustainable development theory. In 2005, Swedish scholar Gössling first introduced eco-efficiency into tourism research. He analyzed the relationship between the environmental damage and economic benefits of tourism, and calculated the tourism eco-efficiency in Rocky Mountains, France, Amsterdam, Siena and other places by using carbon dioxide emission and income index [24]. Since then, the study on the eco-efficiency of tourism began to rise among domestic and foreign scholars. Some scholars carried out the research on the eco-efficiency of tourism from the aspects of tourism destinations, tourism products and tourism transportation (Table 1).

Table 1. Literature for tourism eco-efficiency evaluation. DEA: data envelopment analysis; SBM: slack-based measure.

| Reference            | Method               | Samples                                      | Input                                                   | Desirable Output                     | Undesired Output                |
|----------------------|----------------------|----------------------------------------------|---------------------------------------------------------|--------------------------------------|----------------------------------|
| Brida et al. (2014)  | DEA-BCC model        | Cableways in South Tyrol (2002–2008)         | Labor cost, Asset                                       | Revenue, added value                | —                                |
| Han et al. (2015)    | DEA, DEA-Undesirable model | Five representative provinces in China (2009–2011) | Capital, Labor                                           | Tourism income and taxes             | Tourism carbon emission          |
| Kitikorn et al. (2016) | Single ratio method | Farm Chokchai in Thailand (2009–2011)       | Material consumption, energy consumption, water consumption, solid waste generation, GHG emission | Net sales                            | —                                |
| Qiu et al. (2017)    | Single ratio method  | 31 provinces in China (1995–2014)           | Tourism carbon footprint                                | Total tourism revenue               | —                                |
| Peng et al. (2017)   | SBM-DEA model        | Huangshan National Park (1981–2014)         | Capital, labor, energy consumption, water consumption, food and | Per capita tourism income            | Garbage, sewage and waste gas    |
In the researches of foreign scholars, Kelly used discrete choice experiments to test tourists’ preference for eco-efficiency strategies of tourist destinations [31]. Minoli discussed the key function and significance of the ecological label of tourism destination on sustainable tourism [32]. Brida et al. studied the eco-efficiency of tourist traffic, and put forward some suggestions for the improvement of tourist traffic eco-efficiency [25]. In addition, some studies measured the change of tourism eco-efficiency from the perspective of carbon footprint and carbon emissions in tourism activities [33,34]. Meanwhile, the research by Perch-Nielsen et al. determined the intensity of greenhouse gases in the added value of the Swiss tourism sector through a bottom-up approach, and discussed the results and possible mitigation options [35]. Based on the input–output matrix, Kytzia et al. studied the impact of land use and the change range of tourism employees on the eco-efficiency of tourism land use in Davos [36]. Chinese scholars have also studied the issue of tourism eco-efficiency from different perspectives. Taking the cities in Hubei Province as an example, Zha measured and analyzed the development efficiency and dynamic characteristics of low-carbon tourism economy from 2007 to 2013 [29]. At the same time, he also developed a new model to measure China’s provincial tourism eco-efficiency and the change of ecological productivity from 2005 to 2015 [37]. Qiu calculated and decomposed China’s tourism CO2 emissions, used the tourism eco-efficiency ratio method to discuss its evolution and distribution characteristics, and conducted in-depth analysis of the influencing factors through a panel data regression model [28]. In addition, related researches have also been carried out in the field of tourism eco-efficiency measurement and characteristics [38,39]. However, most of the perspectives of these studies focus on the analysis of specific cases, and they are relatively simple in terms of research scale. They lack the comparison of tourism eco-efficiency at the regional level and a comprehensive analysis of its influencing factors.

At present, there are three main methods for measuring the tourism eco-efficiency, namely the single ratio method, the index system method, and the model method. The single ratio method is calculated by the ratio of economic index and environmental index, which is suitable for the analysis of a single project or technical object. Since it cannot give an optimal ratio set, it lacks practicality at the practical level. The core of the index system method is to construct a comprehensive index of eco-efficiency measurement, which often involves indicators such as tourism input and output, tourism carbon footprint, energy consumption, tourism economy, and environmental effects. Nevertheless, the factors considered in this index may not be comprehensive, and it is difficult to eliminate the influence of subjective empowerment on the evaluation results [6]. Data envelopment analysis (DEA) is the most widely used in the model method to measure tourism eco-efficiency, but it does not consider the factor “slack” and cannot reasonably solve the problem of efficiency evaluation in the presence of undesired output [29]. Some scholars have also used the SBM (slack-based measure) model to study the tourism eco-efficiency [40,41]. This model incorporates undesired outputs and considers the non-radial slack problem of input–output, which compensates for the defects of the traditional DEA model to some extent, but also loses the radial ratio information of input–output variables. This may cause errors in the value of eco-efficiency.

Therefore, this paper introduces the Super-EBM (epsilon-based measure) model based on undesired output into the measurement of tourism eco-efficiency, and constructs an evaluation indicators system for urban tourism eco-efficiency. A comparative study of the tourism eco-efficiency in the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei region from 2008 to 2017 was carried out, and the spatial-temporal evolution characteristics of tourism eco-efficiency and the degree of variation within each urban agglomeration were deeply analyzed.
In addition, we further analyzed the internal reasons affecting the tourism eco-efficiency through the input–output redundancy rate, explored its external influencing factors by using a panel regression model, and put forward practical suggestions for improving the tourism eco-efficiency of cities.

2. Research Methods

2.1. Models

2.1.1. Super-EBM Model

In the early literature, the traditional data envelopment analysis (DEA) method was used to measure eco-efficiency, mainly including BCC and CCR models. However, they are all radial models that only consider the proportional change of input or output elements, and ignore non-radial slack variables without including undesired output indicators. On this basis, Tone [42] proposed a non-radial and non-angle SBM model. This model adds undesired output and considers non-radial relaxation variables, but also the radial proportion information between the actual value of input or output and the target value is lost. For this reason, Tone et al. [43] developed a hybrid EBM (epsilon-based measure) model that includes both radial and non-radial information. The model retains the original proportion information of the front projection value to the greatest extent, and takes the influence of non-radial slack variables into account. It also solves the problem of inconsistent input and output element dimensions, which can more truly and effectively reflect the eco-efficiency of decision-making units (DMU). Different from the previous models, the EBM model introduces the ε parameter which needs to be set before building the model. ε represents the proportion of the non-radial part in efficiency calculation, and the value range is [0,1]. When ε = 0, it is equivalent to radial CCR model; when ε = 1, it is equivalent to SBM model. The general linear program of the unoriented EBM model based on undesired output is as follows:

\[
gamma' = \min \frac{\theta - \varepsilon_x \sum_{i=1}^{n} \frac{w_i S_i}{x_{i0}}}{\phi + \varepsilon_y \sum_{j=1}^{m} \frac{w^r_j y_j}{y_{r0}} + \varepsilon_u \sum_{q=1}^{s} \frac{w^p_q u_q}{u_{q0}}} 
\]

s.t. \[ \sum_{i=1}^{n} x_{ij} \lambda_j + s^r_i = \theta x_{i0}, \quad i = 1,2,..., m \]  
\[ \sum_{j=1}^{m} y_{rj} \lambda_j - s^r_i = \phi y_{r0}, \quad r = 1,2,..., s \]  
\[ \sum_{q=1}^{s} u_{qj} \lambda_j + s^p_q = \phi u_{q0}, \quad p = 1,2,..., q \]

\[ \lambda_j \geq 0, \quad s^r_i, \quad s^r_i, \quad s^p_q \geq 0 \]  

where \( \gamma' \) indicates the eco-efficiency value; \( \lambda_j \) refers to the linear combination coefficient of DMU; \( x_{ij}, y_{rj}, u_{qj} \) denote the \( i \)-th input, \( r \)-th desirable output, and \( p \)-th undesired output of DMU, respectively; \( n, m, s, q \) stand for number of DMUs, inputs, desirable outputs, and undesired outputs, respectively; \( s^r_i, s^r_j, s^p_q \) represent the input slack, desirable output slack and undesired output slack, respectively; \( w_i, w^r_j, w^p_q \) represent for the relative importance of each input, desirable output, and undesired output, respectively; \( \theta \) stands for the radial planning parameter; \( \varepsilon_x, \varepsilon_y, \varepsilon_u \) represent the non-radial weight of input, desirable output, and undesired output, respectively.

Although the EBM model overcomes the shortcomings of the traditional DEA model and SBM model to a certain extent, the efficiency value measured by the EBM model does not exceed 1. When there are many DMUs on the frontier of production, it is not possible to further compare their pros and cons. Based on the method of Andersen and Petersen [44], the ordinary EBM model was improved to a Super-EBM model with a best efficiency value greater than 1, and the eco-efficiency of the tourism industry was measured by the Super-EBM model. When and only when \( \gamma' \geq 1 \), the eco-efficiency of DMU is considered to be in an effective state, and when it is less than 1, the eco-efficiency of input–output elements is considered ineffective. Eco-efficiency, i.e., comprehensive...
efficiency (CE), can be further decomposed into pure technical efficiency (PTE) and scale efficiency (SE). Pure technical efficiency can measure the efficiency level of tourism technology and management. Scale efficiency reflects the impact of the scale effect, and judges whether the current production scale is in the best state. Comprehensive efficiency = pure technical efficiency \times scale efficiency.

2.1.2. Panel Regression Model

Panel data are data with two dimensions: time and space. The general linear model can only process cross-section data and time series data separately, but cannot analyze and compare them at the same time. The panel data regression model proposed by Mundlak (1961) and Balestra and Nerlove (1966) successively considers the internal dynamics of the sample individuals and the differences between the individuals, and greatly expands the sample size, so that the model has a higher degree of freedom, effectively alleviating the problem of collinearity of variables and variability between sample individuals [45,46]. It is mainly divided into three forms: a fixed effect model, a random effect model, and a mixed effect model. This article uses a fixed-effect panel regression model to explore the external factors that affect the eco-efficiency of tourism. The general form of the panel regression model is as follows:

\[ Y_{it} = \alpha + \beta X_{it} + \epsilon_{it}, \quad i = 1,2,...,N; \quad t = 1,2,...,T \]  

(6)

The subscript of \( I \) is used to denote the \( i \)-th cross section and \( t \) denotes time; \( Y_{it} \) and \( X_{it} \) represent the explained variable and explanatory variable, respectively; \( \beta \) indicates the regression coefficient vector and \( \epsilon_{it} \) is the error term; and \( N \) and \( T \) represent the number of individuals observed and the length of time, respectively.

2.2. Index System Construction

2.2.1. Tourism Eco-Efficiency Indicators System

Drawing on previous research experience [30,41] and combining the connotation of tourism eco-efficiency, this paper builds an evaluation indicators system of urban tourism eco-efficiency. It is composed of three parts: input indicators, desirable output indicator, and undesired output indicator. The input–output indicators system is shown in Table 2.

Input indicators: Labor, capital and energy inputs are generally considered to be important factors that constitute industrial development. Considering the availability of city-level data, in this paper we selected the number of employees in the tertiary industry to represent labor input, and the fixed asset investment in the tertiary industry to represent capital input. The fixed asset investment price index is used to convert the amount of investment in fixed assets into the constant price, which takes the year 2008 as the base period. Based on Zhang’s research [47], the energy consumption of the tourism industry is spun off from the energy consumption of the tertiary industry of each province by the tourism development coefficient. The estimated equation is as follows:

\[ E_t = \sum_j E_{ij,t} \times \beta_j \times R_t \]  

(7)

The subscript of \( I \) refers to the \( i \)-th sector related to tourism in the tertiary industry; \( j \) refers to the \( j \)-th energy type; \( E_i \) indicates the total energy consumption of tourism in year \( t \); and \( E_{ij,t} \) stands for the \( j \)-th energy terminal consumption of sector \( i \) in year \( t \). \( \beta_j \) represents the standard coal coefficient of energy \( j \), referring to "General principles for calculation of the comprehensive energy consumption (GB/T2589-2008)". \( R_t \) indicates the tourism development coefficient in year \( t \), that is, the ratio of tourism revenue to the tertiary industry’s GDP. The energy consumption of tourism in prefecture-level cities is stripped by the proportion of each city’s tourism revenue in the province’s total tourism revenue.

Desirable output indicator: This paper selected the total tourism revenue representing economic benefits as the desirable output. It consists of domestic tourism revenue and inbound
tourism revenue. The inbound tourism revenue is converted by the exchange rate of US dollar to RMB over the years and reduced to the constant price based on 2008 according to the consumer price index (CPI).

Undesired output indicator: The greenhouse effect generated by carbon dioxide and other gases is the main cause of global warming. In view of this, this article selects tourism CO\textsubscript{2} emissions as the undesired output to measure the eco-efficiency of tourism. Regarding the measurement of CO\textsubscript{2} emissions in the tourism industry, the predecessors used different methods to study from different scales [48–50], but at present there is not yet a set of commonly recognized methods and systems. Energy consumption is generally considered to be the main source of CO\textsubscript{2} emissions from tourism [51]. Referring to the IPCC greenhouse gas emission nuclear algorithm and Zhang’s method [47], this paper uses tourism energy consumption to measure tourism CO\textsubscript{2} emissions, and the equation is as follows:

\[
TC_t = \sum_{j} E_{ij,t} \times R_j \times V_j \times CEF_j \times COF_j \times \frac{44}{12}
\]  

where \(TC_t\) represents tourism CO\textsubscript{2} emissions in year \(t\); \(V_j\) indicates the average low calorific value of energy \(j\); \(CEF_j\) stands for the carbon content per unit calorific value of energy \(j\); and \(COF_j\) represents the carbon oxidation rate of energy \(j\). The thermal carbon emissions are calculated according to the average calorific value carbon content of raw coal, and electricity is calculated based on the emission factor of the regional power grid baseline published by the China Development and Reform Commission over the years.

### Table 2. Input–output indicators system.

| Indicator type          | Indicator name                  | Primary |
|-------------------------|---------------------------------|---------|
| Input indicators        | Labor input                     | Number of employees in the tertiary industry |
|                         | Capital input                   | Fixed asset investment in the tertiary industry |
|                         | Energy input                    | Tourism energy consumption          |
| Desirable output indicator | Total tourism economy         | Total tourism revenue             |
| Undesirable output indicator | Tourism environmental pollution | Tourism CO\textsubscript{2} emissions |

#### 2.2.2. Indicators of Influencing Factors

Previous studies have shown that factors such as economic development level, structural effects, technological effects, and environmental regulations have varying degrees of impact on eco-efficiency [52–54]. On this basis, combined with the particularity of tourism and the availability of data, this paper selected the indicators of tourism development level, tourism industry status, urbanization level, technological innovation capability, and investment level to explore the influencing factors of tourism eco-efficiency.

Tourism development level: Tourism development level is closely related to the ecological environment of a city, which often affects the tourism eco-efficiency. Drawing on the research of Qiu et al. [28], here we choose per capita tourism revenue (PTR) to characterize the city’s tourism development level.

Tourism industry status: The proportion of tourism in the tertiary industry determines the status of the tourism industry. Tourism industry status reflects the importance attached by the city to the development of tourism, and it affects the eco-efficiency of tourism to a large extent. Tourism industry status (TIS) is characterized by the proportion of tourism revenue in the tertiary industry’s GDP.

Urbanization level: Generally speaking, the level of urbanization affects the city’s economy, technology level, and people’s environmental awareness. Hence, it is an important factor that
influences the eco-efficiency of tourism. Urbanization rate (UR), i.e., the proportion of urban population in the total population, is used here to characterize the level of urbanization.

Technological innovation capability: Technological innovation is the core driving force of current urban development, and is of great significance for sustainable development. The effective integration of technological innovation and the development of the tourism industry can help to improve the eco-efficiency of the tourism industry. Therefore, the number of patents granted to each city (PGN) was selected as an indicator to measure technological innovation capability.

Investment level: The impact of tourism industry investment on tourism eco-efficiency has two sides. On the one hand, the increase of investment expands the scale of the tourism industry. The “scale effect” can promote the development of the tourism industry and increase tourism income. On the other hand, blind investment and repeated construction without detailed investigation and scientific planning will also have a negative impact on the eco-efficiency of the tourism industry. The level of investment is expressed in terms of the fixed asset investment per ten thousand yuan of tourism revenue (FAI).

2.3. Research Area and Data Sources

The Yangtze River Delta, the Pearl River Delta, and the Beijing–Tianjin–Hebei region are currently the three major urban agglomerations with the strongest strength and the most development potential in China’s tourism industry. The three urban agglomerations are rich in tourism resources with the number of China’s excellent tourism cities, scenic spots above the 4A level, and key scenic spots all in the forefront of the country. According to the “Outline of the Yangtze River Delta Regional Integration Development Plan” issued by the State Council of China in 2019, the planning scope of the Yangtze River Delta region has been extended to Jiangsu, Zhejiang, Shanghai, and Anhui. The scope of the Pearl River Delta urban agglomeration contains nine prefecture-level cities in Guangdong Province, including Guangzhou and Shenzhen. The Beijing–Tianjin–Hebei urban agglomeration covers Beijing, Tianjin, and the whole province of Hebei (as shown in Figure 1).

This paper analyzed the panel data of 63 cities in the above three major urban agglomerations from 2008 to 2017. Due to the split of Chaohu City in Anhui Province in 2011, only sixteen prefecture-level cities in Anhui are considered here in order to maintain the consistency of the statistical results. The number of employees in the tertiary industry comes from the China City Statistical Yearbook (2009–2018). The tourism revenue, urbanization rate and the number of patent granted are derived from the statistical yearbooks of various cities. The GDP of the tertiary industry and the fixed asset investment of the tertiary industry are found in the statistical bulletins of the national economic and social development of each city over the years. The energy consumption data are from the regional energy balance table in the China Energy Statistical Yearbook (2009–2018). The missing values of individual years are supplemented by the average growth rate method or the mean value method.
3. Empirical Study

3.1. Eco-Efficiency Measurement Results

The Super-EBM model was used to calculate the 10-year tourism eco-efficiency of 63 cities in the three major urban agglomerations using MAX DEA 7.0 software, and the results are shown in Table 3. Due to space limitations, only the average of the comprehensive efficiency, pure technical efficiency and scale efficiency of each city in 2008–2017 are listed here.

| Region          | City       | CE  | PTE | SE  | Region          | City       | CE  | PTE | SE  |
|-----------------|------------|-----|-----|-----|-----------------|------------|-----|-----|-----|
| Yangtze River   | Nanjing    | 0.902| 0.994| 0.909| Anqing     | 0.619| 0.659| 0.939|
| Delta           | Wuxi       | 0.991| 1.008| 0.983| Huangshan  | 0.907| 0.941| 0.963|
|                 | Xuzhou     | 0.795| 0.821| 0.969| Fuyang     | 0.419| 0.671| 0.623|
|                 | Changzhou  | 0.916| 0.924| 0.992| Suzhou     | 0.424| 0.726| 0.584|
|                 | Suzhou     | 0.978| 1.036| 0.943| Chuzhou    | 0.441| 0.629| 0.698|
|                 | Nanjing    | 0.808| 0.842| 0.960| Luan       | 0.445| 0.576| 0.777|
|                 | Lianyungang| 0.871| 0.996| 0.875| Xuancheng  | 0.475| 0.700| 0.676|
|                 | Huaiian    | 0.800| 0.916| 0.873| Chizhou    | 1.102| 1.174| 0.938|
|                 | Yangzhou   | 0.753| 0.852| 0.884| Bozhou     | 0.437| 0.761| 0.577|
|                 | Yangzhou   | 0.950| 0.955| 0.994| Guangzhou  | 0.638| 0.916| 0.703|
|                 | Zhenjiang  | 1.013| 1.018| 0.995| Shenzhen   | 0.562| 0.635| 0.886|
|                 | Taizhou    | 0.777| 0.886| 0.876| Zhuhai     | 0.589| 0.628| 0.937|
|                 | Suzian     | 0.763| 1.095| 0.699| Foshan     | 0.535| 0.540| 0.991|
|                 | Hangzhou   | 0.748| 0.891| 0.842| Huizhou    | 0.519| 0.564| 0.921|
|                 | Ningbo     | 0.755| 0.797| 0.948| Dongguan   | 0.566| 0.596| 0.950|
|                 | Wenzhou    | 0.730| 0.738| 0.989| Zhongshan  | 0.553| 0.647| 0.855|
|                 | Jiaxing    | 0.776| 0.780| 0.995| Jiangmen   | 0.608| 0.670| 0.909|
|                 | Huzhou     | 0.928| 0.949| 0.977| Zhaoqing   | 0.565| 0.659| 0.858|

Figure 1. Location of study area.
Spatial—Temporal Differences of Tourism Eco-Efficiency in Three Urban Agglomerations

3.2.1. Comprehensive Efficiency

From 2008 to 2017, the eco-efficiency of tourism in the three major urban agglomerations showed a general trend of decline-rise-decline. Compared with that of ten years ago, the eco-efficiency values of the three regions decreased in 2017. Around 2008, China’s tourism industry began to enter a stage of rapid development, and tourism investment increased year by year. However, the possible environmental impact of tourism in this period did not attract widespread attention, which led to the reduction of tourism eco-efficiency in 2008–2010. Since 2011, the eco-efficiency of the three major urban agglomerations has gradually increased. It is closely related to the 2011 “Twelfth Five-Year Plan” of China, which proposed to actively respond to climate change, establish the green development concept of saving resources and protecting the environment, and call on the whole society to establish a low-carbon environmental awareness. In

| Shaoxing     | 0.850 | 0.875 | 0.973 | Beijing     | 0.718 | 1.090 | 0.659 |
|--------------|-------|-------|-------|-------------|-------|-------|-------|
| Jinhua       | 0.886 | 0.909 | 0.975 | Tianjin     | 0.674 | 0.922 | 0.731 |
| Quzhou       | 0.789 | 0.975 | 0.809 | Shijiazhuang| 0.439 | 0.451 | 0.972 |
| Zhourshan    | 0.854 | 0.926 | 0.922 | Tangshan    | 0.428 | 0.460 | 0.932 |
| Taizhou      | 0.820 | 0.828 | 0.991 | Qinhuangdao | 0.609 | 0.657 | 0.926 |
| Lishui       | 0.852 | 0.970 | 0.877 | Beijing–Handan | 0.444 | 0.484 | 0.917 |
| Shanghai     | 0.623 | 1.033 | 0.605 | Tianjin–Hebei| 0.442 | 0.612 | 0.727 |
| Hefei        | 0.466 | 0.493 | 0.949 | Xingtai     | 0.500 | 0.522 | 0.957 |
| Wuhu         | 0.505 | 0.560 | 0.907 | Baoding     | 0.482 | 0.550 | 0.875 |
| Bengbu       | 0.439 | 0.623 | 0.705 | Chengde     | 0.530 | 0.594 | 0.891 |
| Huaian       | 0.441 | 0.808 | 0.546 | Cangzhou    | 0.410 | 0.552 | 0.745 |
| Maanshan     | 0.468 | 0.686 | 0.684 | Langfang    | 0.442 | 0.520 | 0.853 |
| Huaiabei     | 0.435 | 1.154 | 0.380 | Hengshui    | 0.432 | 1.049 | 0.419 |

| Yangtze River Delta | 0.717 | 0.860 | 0.835 | Beijing–Tianjin–Hebei | 0.504 | 0.651 | 0.816 |
| Pearl River Delta  | 0.571 | 0.650 | 0.890 | Overall mean value   | 0.597 | 0.720 | 0.847 |

According to the average eco-efficiency of tourism in each city from 2008 to 2017, referring to Liu’s classification criteria [55], all cities were divided into four levels. Class I (CE ≥ 1) represents cities with the best eco-efficiency, whose tourism input and output are in a valid state; Class II (0.9 ≤ CE < 1) has high eco-efficiency, but it is still in an ineffective state; Class III (0.5 ≤ CE < 0.9) belongs to the middle level; Class IV (CE < 0.5) means low tourism eco-efficiency of city.

As shown in Table 3, there are only nine cities with an average value of tourism eco-efficiency greater than 0.9, accounting for 14.3% of all cities. Among them, only Zhenjiang and Chizhou have a tourism eco-efficiency of more than 1, reaching the frontier of efficiency; seven cities have high eco-efficiency, and all of these best and high-efficiency cities belong to the Yangtze River Delta without exception and are mostly located in Jiangsu Province. The number of cities with medium efficiency is the largest, accounting for 52.4% of the total. The eco-efficiency of the three municipalities of Shanghai, Beijing, and Tianjin, as well as the cities of the Pearl River Delta, are all at this level. There are also 21 inefficient cities, accounting for 33.3% of the total. They belong to Anhui Province in the Yangtze River Delta and Hebei Province in Beijing–Tianjin–Hebei region.

From the provincial level, the green development level of tourism in Jiangsu and Zhejiang province is higher, followed by the three municipalities and Guangdong Province, while Anhui and Hebei province are relatively low. Overall, the average eco-efficiency of tourism in the three urban agglomerations in 2008–2017 is 0.597, which belongs to a medium efficiency level. Among them, the Yangtze River Delta region is 0.717, exceeding the mean value. At the same time, the eco-efficiency of the Pearl River Delta and Beijing–Tianjin–Hebei region are not up to the average level, being 0.571 and 0.504, respectively.
about 2015, the eco-efficiency of major urban agglomerations began to gradually decrease. Among them, the Pearl River Delta region had the most significant change. After a short rise in 2016, the eco-efficiency of the tourism industry in 2017 dropped sharply from 0.621 to 0.506, only 0.9 percentage points higher than that in the Beijing–Tianjin–Hebei region. This is because, under the guidance of industrial policies, various types of capital have turned to be invested in tourism. The direct investment in 2015 alone exceeded one trillion yuan. However, these investments did not produce good results, forming an investment bubble. Besides, some investors only focused on economic interests and blindly developed and constructed projects, even at the expense of the environment. As a result, the eco-efficiency decreased, which had a great negative impact on the sustainable development of tourism.

Among the three major urban agglomerations, the eco-efficiency of the Yangtze River Delta is higher than that of the other two regions, the Pearl River Delta is always at the middle level, and the eco-efficiency of the Beijing–Tianjin–Hebei region is the lowest (Figure 2a). The urban agglomeration of the Yangtze River Delta is located in the middle and lower reaches of the Yangtze River Plain with a mild and humid climate, beautiful environment, and rich eco-tourism resources, which results in a high degree of greening. In addition, there is a three-dimensional transportation network in this region, so that the degree of industrial coordination is high, and the development of each city is relatively balanced. A strong technical innovation ability makes the region a have high level of low carbonation. Relying on favorable geographical location and policy advantages, the Pearl River Delta region has risen rapidly in the 1980s and 1990s by introducing large amounts of foreign capital. Due to the export-oriented economy of this region, small and medium-sized cities directly participate in the division of labor in the global industrial chain and the connection with core cities is not close. Moreover, the regional industrial structure also needs to be upgraded. For a long time, excessive attention has been paid to regional economic development, and insufficient attention has been paid to culture, ecology, etc., which makes a certain gap between the eco-efficiency of the Pearl River Delta and the Yangtze River Delta. The Beijing–Tianjin–Hebei urban agglomeration of North China is in a transitional zone from the semi-humid area to the semi-arid area with a long-term shortage of water resources and a weak ecological foundation. Furthermore, there is a large gap in the level of economic development within the region as well as a lack of deep industrial division and cooperation. The rapid economic growth of Beijing and Tianjin does not play a fine role in radiating to the surrounding cities in Hebei, and the overall coordination of the region is poor, thus affecting the eco-efficiency of the tourism industry.

3.2.2. Pure Technical Efficiency

In terms of pure technical efficiency, the Yangtze River Delta region is still far ahead of the rest, and the range of change is not large, always maintaining above 0.8 (Figure 2b). The pure technical efficiency of the Pearl River Delta and the Beijing–Tianjin–Hebei region are relatively close, with a variation range of 0.58 to 0.72. Similar to the change trend of comprehensive efficiency, pure technical efficiency also experienced a process of first decreasing, then increasing, and then decreasing. The Yangtze River Delta region always focuses on the environmental effects of tourism development. Advanced low-carbon technology and management level and rational and efficient utilization of resources are the main reasons for its higher pure technical efficiency. The Pearl River Delta and the Beijing–Tianjin–Hebei region need to be improved in this respect.

3.2.3. Scale Efficiency

Unlike the comprehensive efficiency and pure technical efficiency, the Pearl River Delta region has the highest scale efficiency among the three major urban agglomerations, followed by the Yangtze River Delta region. The scale efficiency of the Beijing–Tianjin–Hebei region remains the lowest among the three urban agglomerations (Figure 2c). However, the scale efficiency values of the three regions show little difference, and the changes during the ten years are relatively small. The averages of the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei region are 0.835, 0.890, and 0.816, respectively.
The change trends of the scale efficiency in the three urban agglomerations are similar, and have declined slightly in 2017. The scale efficiency of the Beijing–Tianjin–Hebei region is approaching the Yangtze River Delta region year by year. It can be seen that the Pearl River Delta region has a good scale effect, and the scale of tourism development is moderate. Although the Yangtze River Delta region has a relatively high level of scale, the excessive scale of tourism development also brings about “diseconomies of scale”, which leads to input redundancy and the decline of scale efficiency. On the contrary, the development of the Beijing–Tianjin–Hebei region is in good shape. Since most of the cities in the region are still in the stage of increasing returns to scale, appropriate expansion of the scale is conducive to promoting tourism eco-efficiency.

Figure 2. Spatial-temporal evolution trend of comprehensive efficiency (a), pure technical efficiency (b), and scale efficiency (c) in the three urban agglomerations.

3.3. Analysis of Differences within Urban Agglomerations

By calculating the variation coefficient of the tourism eco-efficiency in the three major urban agglomerations from 2008 to 2017, this paper explores the degree of variation within each urban agglomeration. The results are shown in Figure 3. The variation coefficient of comprehensive efficiency in the Yangtze River Delta is the largest, followed by the Beijing–Tianjin–Hebei region. The variation coefficients of the two regions have shown an upward trend in fluctuations over the past decade. From this it can be seen that the comprehensive efficiency within the Yangtze River Delta and the Beijing–Tianjin–Hebei region is quite large, and is expanding further. The variation coefficient of comprehensive efficiency in the Pearl River Delta is the lowest, not exceeding 0.12. This may be due to the fact that the Pearl River Delta region belongs to the same provincial-level administrative region, as well as the adjacent geographical location, similar political and economic
environment, and various policies that have formed slight differences within the region. The variation coefficient of this area has declined in a fluctuating manner, indicating that the difference within the Pearl River Delta is shrinking year by year.

The variation coefficient of pure technical efficiency in the Beijing–Tianjin–Hebei region is the largest among the three major urban agglomerations. According to Table 1, only three cities—Beijing, Tianjin, and Hengshui—have an average pure technical efficiency above 0.9, while other cities in the Beijing–Tianjin–Hebei region are between 0.4 and 0.7. It can be seen that the pure technical efficiency within this urban agglomeration varies greatly. The variation coefficient of the Yangtze River Delta and Pearl River Delta are relatively small, and the changes of the three urban agglomerations are roughly the same. The overall variation coefficient shows an upward trend of fluctuation, indicating that the gap of pure technical efficiency within the regions is gradually expanding.

In terms of scale efficiency, the overall variation coefficients of the three major urban agglomerations are not large, all of which are less than 0.3. The sequence of variation coefficients of scale efficiency is as follows: Yangtze River Delta > Beijing–Tianjin–Hebei > Pearl River Delta. The difference in scale efficiency within the Yangtze River Delta and the Beijing–Tianjin–Hebei region generally shows a trend of first expanding, then shrinking, and then expanding, but the range of change is small. The variation coefficient of scale efficiency of the Pearl River Delta region is low, and the change is relatively stable. In recent years, the internal gap has slightly expanded.

Figure 3. Variation coefficient of comprehensive efficiency (a), pure technical efficiency (b), and scale efficiency (c) in the three urban agglomerations.
3.4. Input–Output Redundancy Rate

In the Super-EBM model, when the eco-efficiency of the DMU is in an inefficient state, radial and slack improvement can make it reach the frontier of efficiency. Redundancy rate is expressed as the ratio between the sum of radial and slack improvement and the actual input (output). The redundancy of input (output) reflects the part of actual input (output) that can improve eco-efficiency. In order to explore the internal factors that affect the tourism eco-efficiency in major urban agglomerations, this paper calculated the average redundancy rate of various input and undesired output in the three urban agglomerations from 2008 to 2017 (Figure 4).

![Figure 4. Input–output redundancy rate of tourism eco-efficiency in the three urban agglomerations.](image)

Among the input factors, labor and capital are the two inputs that have great redundancy for the development of tourism in the three urban agglomerations. The redundancy of labor input is the most important reason for affecting tourism eco-efficiency, as the redundancy rate of each urban agglomeration has reached more than 45%. Among them, the Beijing–Tianjin–Hebei region is as high as 71.47%, indicating that there are a large number of redundant employees, followed by the Pearl River Delta (55.50%), and the Yangtze River Delta (46.92%). The urban agglomeration with the highest degree of capital investment redundancy is still the Beijing–Tianjin–Hebei region, where 54.47% of fixed-asset investment is in a redundant state and is not fully and effectively utilized. Besides, the redundancy rate of capital investment in the Yangtze River Delta and the Pearl River Delta remains at about 37%, and there is still room for improvement. Energy consumption is the least redundant among the three urban agglomerations. The Pearl River Delta has the highest energy input redundancy rate (24.72%), slightly higher than that of the Beijing–Tianjin–Hebei region (24.29%); therefore, the energy utilization ratio of these two regions needs to be improved. The Yangtze River Delta has a much lower input redundancy rate (13.89%), indicating that the development of tourism in this region is relatively less dependent on energy.

In terms of undesired output, the redundancy rate in the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei region is 13.23%, 25.03%, and 33.68%, respectively. It can be seen that there is considerable redundancy of tourism CO₂ emissions in the Beijing–Tianjin–Hebei region. Most of the tourism resources in this area belong to the type of historical and cultural heritage and the development of ecotourism is relatively lagging behind. Although Hebei Province is rich in natural resource types, the development of the local tourism industry has not yet formed a large scale because of its weak tourism foundation and limited market demand. In addition, Beijing and Tianjin have received abundant overseas tourists over the years and long-distance transportation is also the main reason for the CO₂ emissions of the tourism industry [56]. Due to the limitation of the administrative area, the tourism resources in the Pearl River Delta are relatively scarce, and the
tourism development among the internal cities is unbalanced. In 2017, the tourism revenue of Guangzhou and Shenzhen alone accounted for 62.2% of the total tourism revenue of the entire Pearl River Delta. This region has a developed economy and a high level of urbanization. The tourism development modes are mainly shopping tourism, exhibition tourism, and theme park tourism. However, the awareness of low-carbon tourism is relatively insufficient, and the environmental infrastructure remains incomplete. Blessed with unique natural conditions, in recent years, the Yangtze River Delta region has vigorously developed ecotourism and actively promoted various energy-saving and environmental protection technologies. The concept of green development has been fully and effectively implemented. Hence, the redundancy of tourism CO₂ emissions in the region is the lowest among the three urban agglomerations.

3.5. Influencing Factors

According to the panel data of the three major urban agglomerations in 2008–2017, this paper constructed a panel regression model as shown in Equation (9). CE, PTE and SE were used as the dependent variables. Per capita tourism revenue (PTR), the proportion of tourism revenue in the tertiary industry’s GDP (TIS), urbanization rate (UR), number of patent granted (PGN), and fixed asset investment per ten thousand yuan of tourism revenue (FAI) were selected as explanatory variables, and the related variables were processed logarithmically:

\[
EE_t = \alpha_0 + \beta_1 \ln(PTR_t) + \beta_2 TIS_t + \beta_3 UR_t + \beta_4 \ln(PGN_t) + \beta_5 \ln(FAI_t) + \varepsilon_t \tag{9}
\]

where \( EE_t \) represents the tourism eco-efficiency of city \( i \) in year \( t \), \( \alpha_0 \) is a constant term, \( \beta_i \) (\( i = 1, 2, \ldots, 5 \)) represents the undetermined coefficient of each variable, and \( \varepsilon_t \) stands for a random interference item.

In order to avoid the problem of pseudo regression caused by the collinearity of variables and the unsteadiness of sequences, a multiple collinearity test and a unit root test are needed for each variable before regression analysis. As shown in Table 4, the variance inflation factor (VIF) of each variable does not exceed 10 and the average value of VIF is less than 5, indicating that there is no multicollinearity. In this paper, Levin–Lin–Chu and Fisher-ADF (augmented dickey-fuller) methods were used to perform the unit root test on the panel data. As can be seen from Table 5, all variables reject the non-stationary hypothesis at the significance level of 5%, that is, there is no unit root for each variable, which meets the data stability requirements, and thus regression analysis can be performed directly. Through an F test and Hausman test, an individual fixed effect model was selected to perform regression analysis on the panel data. Thus, a panel regression analysis was conducted on Equation (9). The results are shown in Table 6.

| Variable | VIF | 1/VIF |
|----------|-----|-------|
| ln(PTR)  | 6.26 | 0.159753 |
| TIS      | 3.55 | 0.281927 |
| UR       | 3.50 | 0.286028 |
| ln(PGN)  | 2.91 | 0.344034 |
| ln(FAI)  | 2.84 | 0.352490 |
| Mean VIF | 3.81 | —     |

Table 4. Multicollinearity test. VIF: variance inflation factor.

| Variable | Levin–Lin–Chu | Fisher-ADF | Result |
|----------|---------------|-------------|--------|
|          | Adjusted \( t \) | \( P \) value | Modified inv. chi-squared | \( P \) value |        |
| CE       | -8.4062       | 0.0000      | 3.4546 | 0.0003 | stationary |
| PTE      | -8.0925       | 0.0000      | 12.7663 | 0.0000 | stationary |
Sustainability in technology. However, technological innovation has not played its due role to change the scale efficiency will decrease by 0.03%, increase in the number of patent granted, comprehensive efficiency, pure technical efficiency, and significant negative correlation with the ecosystem. Furthermore, people's awareness of environmental protection is also strong, which has a positive effect on the ecosystem. In addition, people's awareness of environmental protection is also strong, which has a positive effect on the ecosystem. Therefore, blindly pursuing the increase of tourism income will lead to the decrease of tourism eco-efficiency.

The promotion of tourism industry status (TIS) has a significant positive effect on comprehensive efficiency and scale efficiency, but has no significant effect on pure technical efficiency. The larger the ratio of tourism income to the tertiary industry, the higher the status of tourism in the tertiary industry. With the characteristics of "low energy consumption, low pollution and low emission", tourism has been highly valued by various regions in recent years. The tourism industry has greatly promoted the national economy and social employment, and has become a strategic pillar industry of the national economy. Further optimizing the structure of the tertiary industry and giving full play to the advantages of the tourism industry will help to improve the tourism eco-efficiency.

Urbanization level can promote the comprehensive efficiency and pure technical efficiency, and both pass the significance test of 1%. With each 1% increase in urbanization rate (UR), comprehensive efficiency and pure technical efficiency will be improved by 0.53% and 0.68%, respectively, which indicates that urbanization level has an important influence on the change of tourism eco-efficiency. In the areas with a high urbanization level, the overall development of the city is generally better, with relatively mature technology of energy conservation and emission reduction and high resource utilization. In addition, people's awareness of environmental protection is also strong, which has a positive effect on the eco-efficiency of tourism in cities.

The technological innovation capability represented by number of patent granted (PGN) has a significant negative correlation with the eco-efficiency of the tourism industry. With every 1% increase in the number of patent granted, comprehensive efficiency, pure technical efficiency, and scale efficiency will decrease by 0.03%, 0.01%, and 0.03%, respectively. Technological progress helps to change the mode of tourism development, improve the quality of tourism development, and reduce environmental pollution [57]. However, technological innovation has not played its due role in the current tourism development. The long-established traditional development model of the

Table 6. Panel data regression results.

|     | CE Coefficient | t-statistics | PTE Coefficient | t-statistics | SE Coefficient | t-statistics |
|-----|----------------|-------------|----------------|-------------|----------------|-------------|
| ln(PTR) | -0.035970 *** | -3.128706 | -0.056566 *** | -3.954515 | 0.012480 | 1.368779 |
| TIS | 0.162781 *** | 5.904439 | 0.044417 | 1.294901 | 0.134710 *** | 6.161014 |
| UR | 0.525139 *** | 5.903919 | 0.678323 *** | 6.129393 | 0.075461 | 1.069709 |
| ln(PGN) | -0.028638 *** | -5.257729 | -0.014353 ** | -2.117927 | -0.027432 *** | -6.350232 |
| ln(FAI) | -0.043347 *** | -3.741113 | -0.064203 *** | -4.453572 | -0.002816 | -0.306401 |
| Constant | 0.869444 *** | 15.785545 | 1.030201 *** | 15.033326 | 0.872588 *** | 19.975922 |

Note: ***, **, and * mean significant at the levels of 1%, 5%, and 10%, respectively.
tourism industry does not match the current technological mainstream including big data, blockchain, the internet of things, artificial intelligence, and other high-tech. In the future, it is necessary to organically integrate technological innovation with the tourism industry, and use innovation to drive the sustainable development of the tourism industry.

The improvement of investment level will have an inhibiting effect on comprehensive efficiency and pure technical efficiency. Despite capital investment being an indispensable part of tourism development, blind and excessive development without scientific and reasonable planning will not only fail to promote the development of tourism, but also cause the waste of resources and destruction of ecological balance. Only by changing the current extensive development mode and focusing on the development of high-quality tourism can the eco-efficiency of the tourism industry be improved.

4. Conclusions and Discussion

4.1. Conclusions

Tourism eco-efficiency uses quantitative methods to analyze tourism economy and environmental pollution, which can effectively measure the quality of tourism input-output and its environmental impact. It has become an important tool for the evaluation of tourism sustainable development. Further deepening the research connotation of tourism eco-efficiency is of great significance to the green and sustainable development of the tourism industry. Therefore, this paper took the three major urban agglomerations of the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei region as examples to conduct an empirical study on the eco-efficiency of tourism, and introduced the Super-EBM model. Taking tourism CO$_2$ emissions as undesired output, an evaluation indicators system of urban tourism eco-efficiency was established. We compared and analyzed the spatial-temporal evolution characteristics of tourism eco-efficiency in the three major urban agglomerations and the variation differences within each urban agglomeration, and discussed the influencing factors of tourism eco-efficiency at both internal and external levels.

First, unlike most previous studies that focused on a single region, this paper conducted a comparative study of the tourism eco-efficiency in the three major urban agglomerations in eastern China, and deeply analyzed its spatial-temporal evolution characteristics as well as formation and evolution mechanisms. In addition, in the research method, a hybrid Super-EBM model combining radial and non-radial distance functions was adopted in this paper, which overcomes the defects of the traditional radial DEA model and non-radial SBM model to a certain extent, and can more accurately measure the eco-efficiency value of tourism. The results show that the overall eco-efficiency of tourism in the three major urban agglomerations is at a medium level, and only a few cities have obtained an effective state. From 2008 to 2017, the eco-efficiency of tourism roughly experienced a process of decline-rise-decline. The eco-efficiency of the Yangtze River Delta is the highest, followed by the Pearl River Delta, and the lowest is of the Beijing–Tianjin–Hebei region. Besides, the pure technical efficiency of the Yangtze River Delta is also much higher than that of the other two regions, which is basically consistent with the research conclusion of Liu et al. on the tourism eco-efficiency of coastal cities in China [55]. In terms of scale efficiency, the three major urban agglomerations are relatively high, and the Pearl River Delta has the highest scale efficiency. The gap between the three urban agglomerations is relatively small. Hence, we should focus on improving the pure technical efficiency of tourism in the future.

Second, there is little analysis on the differences and causes of tourism eco-efficiency within the region in the existing literature. This study finds that there are also certain gaps in the tourism eco-efficiency within each urban agglomeration. Among them, the internal gap within the Yangtze River Delta and the Beijing–Tianjin–Hebei region is relatively large, while the Pearl River Delta is relatively small. This may be related to the fact that the Pearl River Delta urban agglomeration belongs to the same provincial administrative region and has similar political and economic environments, as well as various policies. Except for the Pearl River Delta region, the gap between the other two urban agglomerations tends to widen gradually.
Third, from the perspective of input and output, the redundant input of labor and capital is the main reason for the low eco-efficiency of tourism. Moreover, there is a certain redundancy in tourism CO2 emissions of the three urban agglomerations. The input–output redundancy of the Yangtze River Delta region is the smallest, while the redundancy of the Beijing–Tianjin–Hebei and Pearl River Delta region is relatively serious, which is closely related to the different tourism development modes among various urban agglomerations.

Forth, through the establishment of a panel regression model of individual fixed effect, the external factors that affect the eco-efficiency of tourism were explored. The results indicate that the tourism industry status and urbanization level have a significant positive effect on tourism eco-efficiency, while the tourism development level, technology innovation capabilities and investment level hinder the improvement of tourism eco-efficiency. Among them, the influence of investment level on the tourism eco-efficiency is consistent with the previous findings [6]. However, the negative effect of tourism development level is contrary to the research results of Qiu et al. [28], which may be related to the selection of research areas. Qiu et al. studied the eco-efficiency of tourism in 31 provinces in China. The tourism industry in the vast central and western regions started late and is still at the stage of increasing returns to scale. Therefore, the development of tourism is conducive to the improvement of local environmental quality. Nevertheless, the research scope of this paper is the three major urban agglomerations on the east coast of China. As the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei region all belong to economically developed areas of China, the tourism development level in these regions is generally high, and therefore the excessive development of tourism will also cause pressure on the ecological environment, then affecting the eco-efficiency of tourism.

4.2. Policy Implications

Facing the severe situation of climate change, the traditional tourism development model driven solely by factor input and investment has been difficult to sustain. The current situation of the industry with high consumption and low output does not meet the development needs of sustainable tourism. Therefore, the development of the tourism industry must change from extensive to intensive, from scale to quality, to improve the urban tourism eco-efficiency. Government departments should formulate corresponding policies, improve the supervision mechanism of carbon emissions, and strengthen investment in pollution control of tourism. Tourism enterprises also need to shoulder their own responsibilities by adjusting the mode of operation and focus on creating low-emission and low-pollution eco-tourism products. Short-distance leisure travel should be encouraged, and tourism vehicles use new energy sources to replace fossil fuels as far as possible. Furthermore, we must attach importance to the application of technological innovation in the tourism industry and vigorously develop smart tourism, which can not only provide convenience for tourists and managers, but also have important significance for reducing environmental pollution. In addition, it is necessary to improve the quality and low-carbon environmental awareness of tourism practitioners. They are supposed to do good propaganda work and play a positive role in guiding the behavior of tourists.

Each city should accelerate the construction of new urbanization, optimize the structure of the tertiary industry, and further strengthen the position of tourism in the tertiary industry to promote the eco-efficiency of tourism. The Yangtze River Delta region needs to further improve the scale efficiency on the existing basis. The Pearl River Delta and the Beijing–Tianjin–Hebei region must control the input of labor and capital and avoid blind exploitation. Advanced technologies need to be introduced to improve resource utilization and reduce energy consumption, so that CO2 emissions can be reduced from the source. Besides, it is necessary to improve the mechanism of cooperation and exchange within each urban agglomeration, and strengthen the division of labor and cooperation in the areas of infrastructure, tourism planning, collaborative innovation, and pollution prevention, so that the optimal allocation of resources and the coordinated development of regional integration can be promoted. While developing low-carbon tourism, we must give full consideration to the environmental carrying capacity of tourism destinations and combine economic
and environmental benefits. More attention should be paid to ecological environment protection to achieve the sustainable development of tourism.

4.3. Limitations

This paper explores the spatial-temporal differences of tourism eco-efficiency and its influencing factors of the three major urban agglomerations in China. Although it has made some new discoveries, there are still some limitations. Firstly, due to the difficulty in obtaining data of prefecture-level cities, only tourism CO$_2$ emissions were taken as undesirable output. However, the development of tourism will also cause other aspects of pollution, such as water pollution and solid waste pollution. In future research, the indicators system for eco-efficiency measurement needs to be further improved. Secondly, the selection of factors affecting tourism eco-efficiency is not yet comprehensive. In fact, factors such as residents’ consumption level, environmental regulation intensity, and policy systems may also have some influence on tourism eco-efficiency. Additionally, this paper only took the three developed urban agglomerations in eastern China as examples and thus failed to explore the tourism eco-efficiency and its influencing factors of other urban agglomerations and different scale regions in China. In the future, it is necessary to further study the urban tourism eco-efficiency in various regions of the country and analyze the differences and formation mechanism among eastern, central, and western urban agglomerations, so that targeted policy suggestions can be put forward to promote the green development of the tourism industry in various regions.

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