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Regional Differences in Tourism Eco-Efficiency in the Beijing–Tianjin–Hebei Region: Based on Data from 13 Cities

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Abstract: In order to balance the economic development and ecological impact of tourism, it is essential to study tourism eco-efficiency in the context of sustainable development. This study analyzed regional tourism eco-efficiency based on the panel data of the 13 cities of the Beijing–Tianjin–Hebei region using the super-SBM DEA model. Then, we analyzed the driving factors, compared regional differences, and investigated influencing factors of tourism eco-efficiency by applying the global Malmquist–Luenberger (GML) index, Theil index, and geographically and temporally weighted regression (GTWR) models. The results demonstrate the following: (1) The overall tourism eco-efficiency in the Beijing–Tianjin–Hebei region between 2010 and 2019 was low, but it had an increasing trend. (2) The advancement of technological progress factors was mostly responsible for the increase in tourist eco-efficiency. (3) The results for tourism eco-efficiency were significantly polarizing, but the gap among the 13 cities is gradually narrowing. Regional differences are the main contributors to differences in tourism eco-efficiency. (4) Per capita GDP, the proportion of tertiary industry in GDP, the number of patents granted, and the proportion of urban population in the total population were the main factors affecting tourism eco-efficiency. This study could serve as a model for similar countries and regions seeking to enhance tourism eco-efficiency and achieve the Sustainable Development Goals.

Keywords: tourism eco-efficiency; super-SBM model; global Malmquist–Luenberger index; Theil Index; influencing factors; Beijing–Tianjin–Hebei

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1. Introduction

For the development of ecological, economic, and social sustainability, sustainable development is essential for tackling environmental crises and challenges to ensure a sustainable future for humanity [1]. In 2015, the UN 2030 Agenda for Sustainable Development set 17 goals for sustainable development in the economic, social, and environmental areas [2]. It is crucial to maintain or restore the ecological environment to encourage successful economic and social developments and enhance people's livelihoods [3]. In 2021, China published the Implementation of the 2030 Agenda for Sustainable Development, detailing the progress made toward a number of specific goals, such as eradicating absolute poverty, and improving the ecological environment [4]. Tourism, as a substantial industry, is directly related to the goal of eradicating poverty, fostering decent employment opportunities and economic growth, and creating sustainable cities and communities [5,6].

The tourism industry is one of the country's strategic pillars of economic development [7]. Compared with other industries, tourism consumes fewer resources, causes less environmental pollution, and has a low threshold of development. However, tourism activity causes a series of environmental problems, including tourist overload, air pollution, noise pollution, excessive sewage discharge, etc. [8]. Therefore, the coordination of tourism economic growth and environmental conservation has become a critical issue. The main objective of tourism eco-efficiency is maximum economic and social production, while causing the least amount of resource consumption and environmental harm [9]. It is an effective index to evaluate the sustainable development capacity of tourism [10].

The Beijing–Tianjin–Hebei region, which includes Beijing, Tianjin, and 11 prefecture-level cities in Hebei Province, is situated along China's Bohai Rim region. The particularity of location, climate, landform, and natural resources of the region form the foundation for developing both domestic and inbound tourism. Since the coordinated development of the Beijing–Tianjin–Hebei region has become a national strategy, the region has actively integrated tourism resources to improve product quality and expand the scale of the tourism industry. Analyzing the tourism eco-efficiency of this region can provide experiences and lessons for the development of sustainable tourism in other countries, which is essential for international demonstration.

In 2005, Gössling proposed the concept of tourism eco-efficiency and analyzed the relationship between environmental disruption and tourism economic benefits [11]. Since then, research on tourism eco-efficiency began to expand and cover various perspectives [12]. Scholars mostly focus on measuring tourism eco-efficiency [13,14] and its influencing mechanisms [15,16].

Existing findings indicate that the most popular methods to evaluate tourism eco-efficiency are the single-ratio method and DEA model [17]. The single-ratio method was frequently employed at the beginning of tourism eco-efficiency research. In this measurement method, tourism carbon emissions or carbon footprints were used to represent the negative effects of tourism on the environment, and tourism economic income was used to represent the positive benefits of tourism [18,19]. This method uses the ratio of the positive tourism benefits and negative environmental impact to evaluate the eco-efficiency of regional tourism.

In further research, the DEA model has been frequently utilized. Most studies adopted the traditional SBM-DEA model, a super-efficiency model, and other methods to study tourism eco-efficiency [20,21]. Öender assessed the contribution of benchmarking and tourism management information systems to the sustainable development of urban tourism in Europe using the DEA model [22]. Zha et al. investigated the eco-efficiency of provincial tourism in China using traditional DEA and the non-convex frontier model [23]. Additionally, it was suggested that the industrial structure in central and western regions needed to be adjusted so as to gradually reduce regional heterogeneity. In accordance with the time series SBM-DEA model, Peng et al. measured the eco-efficiency of the Huangshan scenic area in China using input and output data [24]. Li applied the SBM-DEA and spatial autocorrelation (SAC) models to explore the spatial pattern and spillover effect of tourism eco-efficiency in China [25].

With the continuous improvement of research, scholars began to focus on the factors that influence tourism eco-efficiency. Reilly suggested that transportation has a significant impact on tourism eco-efficiency based on a Canadian case study in Whistler [26]. Liu et al. found that the level of economic development, degree of openness, professional level of tourism, and traffic conditions can all significantly increase tourism efficiency [16]. Moreover, some researchers concluded that the economic development level, technological progress level, and urbanization level are key factors that influence tourism eco-efficiency [5,27,28].

In the past, researchers have conducted relatively extensive studies on tourism eco-efficiency, but these were devoted to exploring tourism eco-efficiency at a national and provincial level, while there were few studies conducted at a city level. Studies revealing regional differences from a two-dimensional perspective of geographic space and time to comprehensively evaluate tourism eco-efficiency are even rarer. With this context in mind, we comprehensively applied the super-SBM model based on undesired output, global Malmquist–Luenberger index model, coefficient of variation, and Theil index methods to explore the regional differences of tourism eco-efficiency in the Beijing–Tianjin–Hebei region. Then, we utilized the GTWR model to investigate the influencing factors of regional differentiation of tourism eco-efficiency. The results of this study could provide policy suggestions for sustainable tourism development in the Beijing–Tianjin–Hebei region and serve as a guide for other countries and regions experiencing a similar rapid tourism growth.

2. Research Methods and Data Sources

2.1. Research Methods

2.1.1. Super-Efficiency SBM-DEA Model

DEA is a linear programming method that assesses the relative effectiveness of decision-making units (DMUs), which avoids presetting production functions and does not include a parameter estimation of the model [29]. However, the traditional DEA model is unable to take into account the relaxation of input–output variables because it depends on the characteristics of radial measurement. The super-efficiency SBM model can solve this problem and calculate the efficiency of the effective DMUs, so that it makes the efficiency measurement results more objective and accurate [30]. Due to the above considerations, we measure tourism eco-efficiency in the Beijing–Tianjin–Hebei region by applying a super-efficiency SBM-DEA model containing undesirable outputs and evaluate the DMUs using MaxDEA8.3 software. MaxDEA is a convenient and powerful DEA software, which contains a large number of the latest DEA methods, and provides the combined application of various DEA methods as much as possible. The expression is written as follows:

$$\rho^* = \min \frac{1 + \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{xik}}{1 - \frac{1}{q1+q2}\left[\sum_{r=1}^{q1}\frac{s_r^+}{y_{rk}} + \sum_{t=1}^{q2}\frac{s_t^{b-}}{b_{tk}}\right]} \quad (1)$$

$$\begin{aligned} \text{s.t.} \quad & \sum_{j=1,j\neq k}^{n} x_{ij}\lambda_j - s_i^- \le x_{ik} \\ & \sum_{j=1,j\neq k}^{n} y_{rj}\lambda_j + s_r^+ \ge y_{rk} \\ & \sum_{j=1,j\neq k}^{n} b_{tj}\lambda_j - s_i^{b-} \le b_{tk} \\ & \lambda, s^-, s^+, s^{b-} \ge 0 \\ & i = 1,2,\ldots,m; r = 1,2,\ldots,q_1; t = 1,2,\ldots\ldots,q_2; j = 1,2,\ldots,n(j\neq k) \end{aligned}$$

In Formula (1), j represents each DMU; n is the number of DMU; m and q_1, q_2 denote input, desired output, and undesired output, respectively; and s_i^-, s_r^+, s_t^{b-} represent input slack, desired output slack, and undesired output slack, respectively.

When $\rho^* \ge 1$, it means that the eco-efficiency of DMUs is effective; when $\rho^* < 1$, it is invalid, and the corresponding adjustment of input, desired output, and undesired output is necessary to change the tourism eco-efficiency.

2.1.2. Global Malmquist–Luenberger Index

The super-efficiency SBM model measures tourism eco-efficiency at the frontier of a single year. It is a static efficiency that cannot adequately describe the transformation of eco-efficiency. To solve this problem, the global Malmquist–Luenberger (GML) index is applied to quantify dynamic changes in tourism eco-efficiency. GML index takes into account the green development demands of desired output increase and undesired output decrease. Therefore, this study adopts a GML index method based on global correlation to investigate dynamic changes of tourism eco-efficiency. According to Oh [31], taking the t period as the base period, the GML index expression is as follows:

$$\begin{aligned} \text{GML}_t^{t+1} &= \frac{1+D^G\left(x^t,y^t,b^t;g_{y,}^t-g_b^t\right)}{1+D^G\left(x^{t+1},y^{t+1},b^{t+1};g_{y,}^{t+1}-g_b^{t+1}\right)} \\ &= \frac{1+D^t\left(x^t,y^t,b^t;g_{y,}^t-g_b^t\right)}{1+D^{t+1}\left(x^{t+1},y^{t+1},b^{t+1};g_{y,}^{t+1}-g_b^{t+1}\right)} \times \left[\frac{1+D^G\left(x^t,y^t,b^t;g_{y,}^t-g_b^t\right)}{1+D^t\left(x^t,y^t,b^t;g_{y,}^t-g_b^t\right)} \times \frac{1+D^{t+1}\left(x^{t+1},y^{t+1},b^{t+1};g_y^{t+1}-g_b^{t+1}\right)}{1+D^G\left(x^{t+1},y^{t+1},b^{t+1};g_y^{t+1}-g_b^{t+1}\right)}\right] \\ &= \text{EC}_t^{t+1} \times \text{TC}_t^{t+1} \end{aligned}$$

$$D^G(x^t, y^t, b^t; g^y; g^b) = \text{Max}\{\gamma|(y^t + \gamma g^y, b^t - \gamma g^b) \in P^G(x)\} \quad (2)$$

In Formula (2), x, y, and b stand for the variable of input, desired output, and undesired output, respectively; D^G denotes the global directivity distance function; and γ is the directional distance function value calculated by maximizing the desired output and minimizing the undesired output.

If $GML_t^{t+1} > 1$, it means that the relative efficiency increases from t-th to (t + 1)-th period, and the high value represents a high growth rate. On the contrary, if $GML_t^{t+1} < 1$, the relative efficiency decreases. In addition, the GML index can be further decomposed into technological efficiency change (EC) and technological progress change (TC). Zofio decomposed EC into pure technical efficiency change (PEC) and scale efficiency change (SEC), as well as decomposing TC into pure technology change (PTC) and scale technology change (STC) [32]. It is expressed as Formula (3):

$$\text{GML} = \text{EC} \times \text{TC} = \text{PEC} \times \text{SEC} \times \text{PTC} \times \text{STC} \tag{3}$$

2.1.3. Coefficient of Variation and Theil Index

The coefficient of variation and Theil index are adopted to measure the degree of relative difference of regional tourism eco-efficiency. Larger values represent higher degrees of relative difference. The coefficient of variation can be written as Formula (4):

$$\text{CV} = \frac{1}{\overline{y}} \sqrt{\frac{\sum_i^n (y_i - \overline{y})^2}{(n-1)}} \tag{4}$$

The Theil index is a mathematical method for measuring regional differences based on information entropy [33]. The Theil index has a good decomposability and is widely employed in empirical research of the regional differences in economics, geography, and sociology, both overall and between areas. In this study, the Theil index was adopted to measure the regional differences in tourism eco-efficiency and its spatial differentiation characteristics in the Beijing–Tianjin–Hebei region. The formulas are as follows:

$$T = \frac{1}{n} \sum_{i=1}^{n} \frac{y_i}{\overline{y}} \log\left(\frac{y_i}{\overline{y}}\right) \tag{5}$$

$$T_p = \frac{1}{n_p} \sum_{i=1}^{n_p} \frac{y_{pi}}{\overline{y_p}} \log \frac{y_{pi}}{\overline{y_p}} \tag{6}$$

$$T = T_w + T_b = + \sum_{p=1}^{p} \frac{n_p}{n} \times \frac{\overline{y_p}}{\overline{y}} \times \mathrm{T}_p \sum_{p=1}^{p} \frac{n_p}{n} \times \frac{\overline{y_p}}{\overline{y}} \times \log \frac{\overline{y_p}}{\overline{y}} \tag{7}$$

In Formulas (5)–(7), T represents the Theil index of tourism eco-efficiency, which stands for the overall difference; y_i indicates the tourism eco-efficiency of the i-th city; $\overline{y}$ is the average value of tourism eco-efficiency of the 13 cities in the Beijing–Tianjin–Hebei region; n and p represent the total number of cities and the number of groups, respectively; n_p stands for the number of cities in group p; and y_p represents tourism eco-efficiency of cities in group p. Assuming that n samples are split into p groups with n_p samples in each group, the Theil index can be further decomposed into the within-group difference T_w and between-group difference T_b.

2.1.4. Geographically and Temporally Weighted Regression Model

The geographically weighted regression (GWR) model is adopted to estimate the impact of driving factors on different regions, which is an important tool for studying spatial heterogeneity [34]. However, the GWR model only focuses on spatial dimensions and fails to investigate the time dimension. Therefore, a geographically and temporally weighted regression model (GTWR) was proposed to effectively estimate factor parameters by solving the problem of limited numbers of cross section data samples, and considering the non-stationarity of time and space [35]. The formula is as follows:

$$y_i = \beta_0(u_i, v_i, t_i) + \sum_{i=1}^{k} \beta_i(u_i, v_i, t_i)x_{ik} + \varepsilon_i \quad (8)$$

In Formula (8), y_i represents tourism eco-efficiency of the *i*-th region; (u_i, v_i, t_i) stand for the spatial–temporal dimension coordinates of the *i*-th region; β_0 (u_i, v_i, t_i) denotes the constant terms of the *i*-th region; β_i (u_i, v_i, t_i) indicates the regression parameter of the explanatory variable *k* in the *i*-th region.

2.2. Indicators Selection

2.2.1. Input and Output Variables

Considering previous research [36,37], we created an indicators system to evaluate urban tourism eco-efficiency, as indicated in Table 1.

Table 1. Input–output indicators of regional tourism eco-efficiency.

Category	Indicator Name	Variable	Unit
Input indicators	Tourism resource input	Number of class A and above scenic spots	-
	Labor input	Number of employees in tertiary industry	Ten thousand people
	Capital input	Tourism fixed-asset investment	CNY 100 million
Desired output indicators	Tourism income	Total tourism revenue	CNY 100 million
Undesired output indicators	Tourism environmental pollution	Tourism wastewater discharge	Ten thousand cubic meters
		Tourism SO_2 emission	Ten thousand tons
		Tourism domestic garbage removal volume	Ten thousand tons

(1) Input indicators

In traditional economic systems, the most fundamental factors are labor, capital and land. Especially for tourism, which is a tertiary industry, labor and capital are particularly essential indicators for evaluating eco-efficiency. In addition, tourism resources are a key indicator for evaluating the development of the tourism industry. Taking into account the accessibility of city-level data, we selected the number of class A and above scenic spots to represent the tourism resources input, the number of employees in tertiary industry to represent labor input, and tourism fixed-asset investment to represent capital input. Considering the studies by Yang [38], Li et al. [25], and Cheng [36], the value of tourism fixed-asset investment is converted by the original indicators of fixed-asset investment, multiplying the proportion of tourism revenue in GDP.

(2) Desired output indicators

In general, tourism income is regarded as a suitable indicator of desired output [39]. In this study, total tourism revenue was selected to represent economic benefit. It includes inbound tourism revenue and domestic tourism revenue.

(3) Undesired output indicators

Generally, tourism economic activities produce a lot of waste water, waste gas, and garbage. Therefore, we selected tourism wastewater discharge, tourism SO_2 emission, and tourism domestic garbage removal volume as the undesired output indicators. The calculation methods of the three variables are the same as those of the tourism fixed-asset investment.

2.2.2. Influencing Factor Variables

Based on the existing studies, the following dependent variables and influencing factor variables were selected by combining them with the GTWR method. (1) Tourism eco-efficiency values in various cities between 2010 and 2019 were selected as dependent variables. (2) The economic development level is represented by the per capita GDP (X1). (3) The industrial structure is represented by the proportion of added value of the tertiary industry in the GDP (X2). (4) The technical level is characterized by the number of patents granted (X3). (5) The proportion of urban population in the total population of the city (X5) represents urbanization.

2.3. Data Sources

The data for this study were obtained from the China City Statistical Yearbook (2011–2020), China Urban Construction Statistics Yearbook (2010–2019), Beijing Statistical Yearbook (2011–2020), Tianjin Statistical Yearbook (2011–2020), Hebei Economy Yearbook (2011–2020), and the statistical bulletins on the national economic and social development of each city from 2010 to 2019. This study uses the linear interpolation method to complete some missing data about the number of class A and above scenic spots.

3. Research Results and Analysis

3.1. Statistical Analysis of Tourism Eco-Efficiency

Based on the super-efficiency SBM-DEA model with undesired outputs, this study used MaxDEA8.3 software to calculate tourism eco-efficiency in the 13 cities of the Beijing–Tianjin–Hebei region between 2010 and 2019. MaxDEA is a convenient and powerful DEA software, which contains a large number of the latest DEA methods, and provides the combined application of various DEA methods as much as possible.

Between 2010 and 2019, the mean tourism eco-efficiency score for the Beijing–Tianjin–Hebei region was 0.846, with a general upward trend ranging from 0.803 to 0.940; the results are shown in Table 2. During this time, Beijing had the highest eco-efficiency, while Hengshui had the lowest. With the addition of Xingtai, Baoding, and Chengde, the number of relatively effective areas significantly increased from six to nine during the study period. Therefore, we can infer that the total degree of eco-efficiency in the tourism industry is steadily rising.

Table 2. Measurement results of tourism eco-efficiency.

City	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Beijing	1.116	1.132	1.162	1.176	1.179	1.202	1.196	1.188	1.212	1.268	1.183
Tianjin	1.211	1.204	1.193	1.188	1.175	1.142	1.114	1.177	1.080	1.040	1.152
Shijiazhuang	0.385	0.447	0.459	0.498	0.464	0.570	0.594	0.453	0.659	0.779	0.531
Tangshan	1.032	1.075	1.066	1.058	0.800	1.032	1.035	0.415	0.869	1.013	0.939
Qinhuangdao	1.017	1.003	0.592	0.635	1.001	1.016	1.037	1.098	1.098	1.125	0.962
Handan	0.541	0.538	0.607	0.649	0.528	0.646	0.621	0.350	0.672	0.571	0.572
Xingtai	0.475	0.534	0.565	0.570	0.553	0.588	0.625	0.172	0.561	1.022	0.567
Baoding	0.793	0.814	0.865	1.051	1.048	0.847	1.019	0.494	1.057	1.043	0.903
Zhangjiakou	0.358	0.321	0.381	0.427	0.432	0.509	0.590	1.017	0.589	0.556	0.518
Chengde	0.670	1.026	1.044	1.042	1.071	1.058	1.085	1.004	1.112	1.089	1.020
Cangzhou	1.212	1.155	1.149	1.168	1.138	1.053	1.121	0.255	1.137	1.110	1.050
Langfang	1.107	1.117	1.081	1.076	1.106	1.145	1.141	1.060	1.152	1.113	1.110
Hengshui	0.516	0.517	0.538	0.507	0.458	0.507	0.566	0.255	0.611	0.488	0.496
Mean	0.803	0.837	0.823	0.850	0.843	0.870	0.903	0.688	0.908	0.940	0.846

By analyzing the measurement results, the evolution characteristics of tourism eco-efficiency were further investigated. First of all, the differences in tourism eco-efficiency among the 13 cities were evident. During the ten-year study period, the top five cities were Beijing, Tianjin, Langfang, Cangzhou, and Chengde, indicating that resource consumption and environmental pollution were relatively low in the tourism economic development of these cities. Secondly, some cities reached their highest eco-efficiency with a tourism eco-efficiency greater than 1 for each year between 2010 and 2019. Among these, Beijing, Tianjin, and Langfang were in a complete effective state during the study period. In addition, Chengde, Cangzhou, Qinhuangdao, Tangshan, Baoding, and Zhangjiakou had a relatively complete efficiency for 9 years, 9 years, 8 years, 7 years, 5 years, and 1 year, respectively. The results show that Beijing, Tianjin, and Langfang are the leaders of tourism green development in the region. By contrast, the tourism eco-efficiencies of Zhangjiakou, Hengshui, and Xingtai are relatively low: below 0.6. The lowest efficiency was recorded in the area of Xingtai in 2017. The results demonstrate that these cities took the economic growth approach of "high investment, low utilization of resources and high emissions", which significantly restricted the development of tourism eco-efficiency. Therefore, the industry structure needs to be adjusted for more development opportunities in the future.

Comprehensive tourism eco-efficiency (TE) can be categorized into pure technical efficiency (PTE) and scale efficiency (SE). Pure technical efficiency is influenced by management ability and technical level, and it reflects resource allocation and utilization. The scale efficiency is affected by the factor input scale and reflects economies of scale. According to Figure 1, tourism eco-efficiency has a small change range and illustrates a trend of fluctuating growth. However, comprehensive efficiency and scale efficiency are relatively low and not fully effective, indicating that the tourism investment in the region has not been effectively utilized and there is a loss of efficiency. However, its growth trend shows that tourism in the Beijing–Tianjin–Hebei region is well supported by tourism polices at national and city levels. In addition, pure technical efficiency was significantly better than comprehensive efficiency and scale efficiency, which indicates that technological innovation promotes the eco-efficiency in tourism industry. In the future, the tourism industry will further benefit from the successful development of technology and innovation in tourism products.

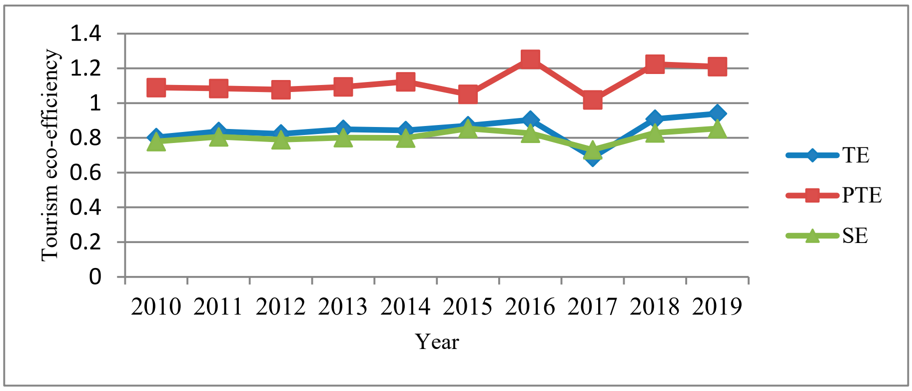

Figure 1. The evolution trend of tourism eco-efficiency.

3.2. Dynamic Analysis of Tourism Eco-Efficiency

The mean GML index of tourism eco-efficiency in the Beijing–Tianjin–Hebei region was 1.224 during the study period. Between 2010 and 2019, the GML index values all exceeded 1, except the minima between 2016 and 2017, which had a variation index of below 1. This indicates that tourism eco-efficiency has increased with the successful development and efficiency of a green tourism economy. This is consistent with the endorsement of national and regional policies, which promote the strategic status of the Beijing–Tianjin–Hebei region, an increase in energy conservation and reduction in emissions, and rapid tourism development. The Outline of the Beijing–Tianjin–Hebei Coordinated Development Plan and other policy documents explicitly develop a circular economy and promote ecological protection. According to the National Eco-Tourism Development Plan (2016–2025) [40] for Hebei province—which incorporates two inter-provincial, high-quality, eco-tourism routes and one provincial, high-quality, eco-tourism route—Yanshan Taihang Mountain is an eco-tourism cooperation area. During the study period, the Government intensified its efforts to foster the growth of tourism, and a series of policy documents, such as

Opinions of Promoting All-area Tourism-based Development, Opinions of Promoting Tourism Industry Reform and Development, and Opinions about Further Stimulating the Culture and Tourism Consumption Potential, were issued by the State Council. The policies encouraged the integration of tourism resources and the expansion of the tourism industry, strengthening the development of tourism in the Beijing–Tianjin–Hebei region.

From the perspective of time series changes, the growth rate of tourism eco-efficiency fluctuated slightly between 2010 and 2015; while, between 2015 and 2019, this rate was high. During the period between 2016 and 2017, the GML index of tourism eco-efficiency was below 1, demonstrating that the rate of tourism eco-efficiency in the Beijing–Tianjin–Hebei region was negative in these two years. Between 2017 and 2018, tourism eco-efficiency rapidly increased due to three major reasons: Firstly, the report of the 19th National Congress of the Communist Party of China put forward new goals and requirements for ecological civilization construction to further "promote green development" and "strengthen energy conservation and environmental protection industry", providing policy support to enhance tourism eco-efficiency. Secondly, a series of environmental policies began to be implemented in this phase, leading to effective energy conservation and reductions in emissions in each city. Thirdly, China adopted strict environmental governance measures between 2017 and 2018 that reduced the environmental cost of tourism development and greatly improved the tourism eco-efficiency in the Beijing–Tianjin–Hebei region.

At a city level, the average GML index of tourism eco-efficiency for each city is also significantly different. Cangzhou had the highest average GML index of 1.709, which indicates that the average growth rate of tourism eco-efficiency was 70.9%; while, Tianjin had the lowest average GML index of 1.078, which indicates an annual growth rate of 7.8%. According to Table 3, tourism eco-efficiency rapidly grew in all cities of the Hebei province. The average rate of increase was more than 20% in Xingtai, Chengde, Cangzhou, and Langfang and between 10% and 20% in Shijiazhuang, Tangshan, Qinhuangdao, Baoding, Handan, Zhangjiakou, and Hengshui. The rate of increase for Beijing is slightly lower at 10%. This is due to the different foundation and policy environment of tourism development in different cities. Beijing and Tianjin have a solid tourism development foundation and a relatively developed tourism economy. In addition, they are strict in the management of sewage treatment and garbage treatment, thereby the level of tourism eco-efficiency is always relatively high in those two cities. Affected by the law of diminishing marginal effect, the growth rate of tourism eco-efficiency is relatively stable. Under the background of the coordinated development of the Beijing–Tianjin–Hebei region, tourism is rapidly developing in Hebei province, influenced by the support of national policy and the spatial spillover effect of the tourism economy in Beijing and Tianjin. Furthermore, due to the strict governance of environmental pollution, tourism eco-efficiency in Hebei has been widely promoted.

Table 3. GML index of tourism eco-efficiency.

City	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018	2018–2019	Mean
Beijing	1.132	1.084	1.064	1.052	1.015	1.098	1.066	1.109	1.283	1.100
Tianjin	1.178	1.165	1.054	1.043	0.877	1.120	1.117	1.146	1.000	1.078
Shijiazhuang	1.392	1.041	1.091	0.942	1.223	1.147	0.842	1.580	1.192	1.161
Tangshan	2.041	0.988	0.752	0.998	0.998	1.050	0.453	2.287	1.005	1.175
Qinhuangdao	1.085	0.967	1.037	1.095	1.032	1.237	0.933	1.810	1.052	1.139
Handan	1.259	1.037	1.117	0.823	1.095	1.059	0.657	1.928	1.080	1.117
Xingtai	1.273	1.014	0.965	0.970	1.105	1.070	0.273	4.212	1.267	1.350
Baoding	1.256	1.048	1.432	0.817	0.890	1.129	0.664	2.102	1.169	1.167
Zhangjiakou	1.254	1.147	1.147	1.064	1.054	1.216	0.786	1.637	1.074	1.153
Chengde	1.374	0.927	0.991	1.081	1.017	1.245	0.656	2.464	1.237	1.221
Cangzhou	1.400	0.990	0.996	0.991	0.856	1.164	0.130	8.094	0.759	1.709
Langfang	1.119	1.007	1.050	1.453	0.964	1.017	0.209	4.912	1.038	1.419
Hengshui	1.281	1.078	1.001	0.924	1.092	1.011	0.549	2.236	0.942	1.124
Mean	1.311	1.038	1.054	1.020	1.017	1.120	0.641	2.732	1.085	1.224

3.3. Driving Factors Analysis of Tourism Eco-Efficiency

Between 2010 and 2019, the GML index of tourism eco-efficiency in the Beijing–Tianjin–Hebei region shows fluctuant increases, which indicate that the green development concept was well-implemented in the tourism industry. However, the technological efficiency change (EC) and the technological progress change (TC) are not stable between 2010 and 2019, with the average growth rates of 9.2% and 11.7%, respectively. This demonstrates that the growth of tourism eco-efficiency is determined by their cross effect, while technological progress plays an important role. During the study period, technological improvements in green tourism in the Beijing–Tianjin–Hebei region were prioritized, especially in the period of 2017–2018. During this time, the technological progress growth rate was 68.6%, suggesting that Beijing–Tianjin–Hebei region put an emphasis on keeping a balance between tourism development and ecological protection, and constantly developed new technologies to promote technological progress, which has become the main driving force for improving tourism eco-efficiency. In addition, technological efficiency experienced considerable growth, which is closely connected to the promotion of tourism management level, tourism resource allocation, and regional tourism industry information sharing, indicating that the trend of intensive development in the tourism industry will become more significant.

Table 4 demonstrates the average value of the GML index and the decomposition index of tourism eco-efficiency of the 13 cities. With regard to changes in technological efficiency and technological progress, the values of all other cities are greater than 1, except for Tianjin. It can be inferred that these two driving forces both promoted tourism eco-efficiency, and various advantages of the tourism industry in the region have been fully utilized. The change in technological progress in Tianjin, which exceeded a value of 1, indicated that its contribution to the enhancement of productivity was greater than that of technical efficiency. The decline of technical efficiency has affected the growth rate of tourism eco-efficiency in Tianjin. In order to encourage the growth of tourism eco-efficiency, the tourism industry's resource allocation efficiency and management level must be increased.

The further decomposition of the technological efficiency change index and technological change index is shown in Table 4. This shows that the technological efficiency change in the tourism industry was alternately affected by pure technological efficiency change (PEC) and scale efficiency change (SEC). The technological progress change index was mainly influenced by the scale technological change index between 2010 and 2017, inferring that the scale of the tourism industry was expanding during this time, but the introduction of tourism management talents and the research of new technologies in the tourism industry were relatively unproductive. Between 2018 and 2019, it was mainly affected by the pure technological change index, but the scale of technological change index decreased, indicating that the technological progress of tourism was significant, but no scale technological effect was formed.

Table 4. The GML index and decomposition results of tourism eco-efficiency.

City	GML	EC	PEC	SEC	TC	PTC	STC
Beijing	1.100	1.014	1.008	1.019	0.999	1.009	0.991
Tianjin	1.078	0.984	0.998	0.977	1.034	1.020	1.014
Shijiazhuang	1.161	1.097	1.113	1.191	1.079	1.113	0.975
Tangshan	1.175	1.082	1.021	1.258	1.010	1.010	1.001
Qinhuangdao	1.139	1.038	1.003	1.042	1.124	1.006	1.116
Handan	1.117	1.058	1.024	1.188	1.127	1.100	1.032
Xingtai	1.350	1.295	1.115	1.724	1.106	0.992	1.235
Baoding	1.167	1.103	1.033	1.258	1.069	1.073	1.000
Zhangjiakou	1.153	1.089	1.059	1.003	1.240	1.179	1.061
Chengde	1.221	1.067	1.007	1.071	1.114	1.094	1.018
Cangzhou	1.709	1.288	1.215	1.787	1.029	0.629	3.841
Langfang	1.419	1.002	0.996	1.028	1.097	1.055	1.133
Hengshui	1.124	1.085	1.021	1.278	1.116	1.028	1.223

3.4. Regional Difference Analysis of Tourism Eco-Efficiency

3.4.1. Overall Regional Differences

We selected the coefficient of variation and Theil index to investigate the regional differences in tourism eco-efficiency in the Beijing–Tianjin–Hebei region. As shown in Figure 2, the coefficient of variation and decrease in Theil index fluctuated from 0.406 and 0.035 in 2010 to 0.269 and 0.016 in 2019, respectively. This suggests that the gap in tourism eco-efficiency among these cities is narrowing because tourism economics is becoming more balanced and efficient. That is to say, with the gradual development of tourism's economic advantages, various cities can make full use of resource endowments and technological advantages in tourism, and the allocation of tourism resources tends to be balanced. Moreover, it should be noted that the variation coefficient and Theil index significantly increased, reaching a maximum value in 2017, which may be closely related to the strict environmental protection policies and other external environmental changes in 2017, causing a significant increase in the relative difference of urban tourism eco-efficiency in the Beijing–Tianjin–Hebei region.

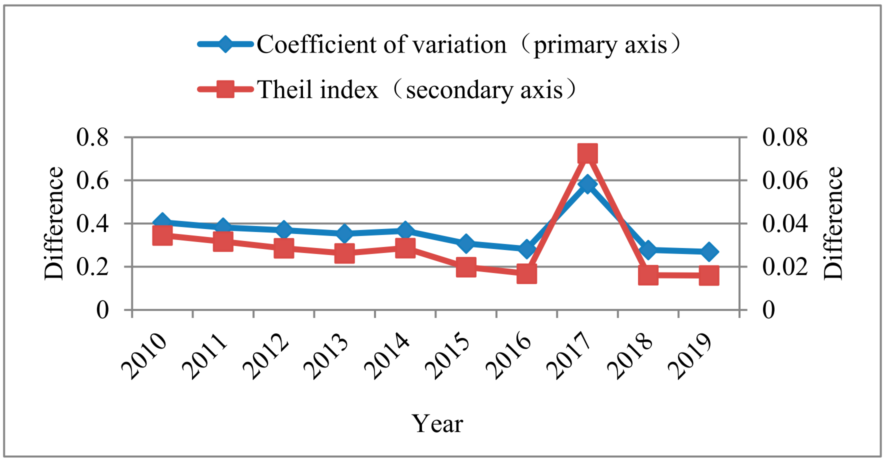

Figure 2. Regional differences of tourism eco-efficiency in Beijing–Tianjin–Hebei region.

3.4.2. Overall Difference Decomposition

The above analysis can interpret the general evolution characteristics of regional differences in tourism eco-efficiency, but it cannot determine underlying causes. Referring to the study by Weng [41], the Beijing–Tianjin–Hebei region can be divided into three areas: northern, central, and southern areas. The north area, which includes Zhangjiakou, Chengde, and Qinhuangdao, is an ecological conservation area. The central part is a central core functional area with a high level of tourism economic development, including Beijing, Tianjin, Tangshan, Langfang, Baoding, and Cangzhou. In the southern functional expansion area, major cities include Shijiazhuang, Hengshui, Xingtai, and Handan, most of which are far away from the core area of the capital. With the purpose of further evaluating the regional differences in tourism eco-efficiency, we decomposed these differences using the Theil index.

According to the decomposition results (Table 5), the Theil index in the northern region was the largest, showing general fluctuant decreases from 0.035 in 2010 to 0.019 in 2019. This shows that the difference in tourism eco-efficiency among cities in the southern area is the largest, but it is gradually narrowing. The Theil index of the central area and southern area followed that of the northernarea, but the differences in tourism eco-efficiency among cities remained stable during the study period. On the whole, the regional differences of tourism eco-efficiency have been narrowing, suggesting that the eco-efficiency of the tourism industry in northern, central, and southern areas is evolving toward equilibrium.

Table 5. Theil index and its decomposition results of tourism eco-efficiency.

Year	Global Theil Index	Theil Index between Groups	Proportion of Differences between Groups	Group Theil Index	Proportion of Intra-Group Differences	Northern Area Theil Index	Central Area Theil Index	Southern Area Theil Index
2010	0.035	0.025	71.2%	0.010	28.8%	0.035	0.004	0.003
2011	0.032	0.020	63.4%	0.012	36.6%	0.044	0.003	0.001
2012	0.029	0.020	69.8%	0.009	30.2%	0.036	0.002	0.002
2013	0.026	0.020	76.0%	0.006	24.0%	0.028	0.001	0.003
2014	0.029	0.020	69.3%	0.009	30.7%	0.029	0.003	0.001
2015	0.020	0.013	67.9%	0.006	32.1%	0.020	0.003	0.002
2016	0.017	0.013	77.9%	0.004	22.1%	0.014	0.001	0.000
2017	0.073	0.038	52.9%	0.034	47.1%	0.000	0.059	0.026
2018	0.016	0.011	67.3%	0.005	32.7%	0.016	0.002	0.001
2019	0.016	0.007	43.1%	0.009	56.9%	0.019	0.001	0.018

3.5. Analysis of the Influencing Factors of Tourism Eco-Efficiency

We established a GTWR model to assess the elements affecting tourism eco-efficiency. In order to prevent variation in the regression results due to multicollinearity across variables, we conducted a collinearity test on the selected factors prior to model establishment. The variance inflation factors of the independent variables were all below 10. According to the validation results of the GTWR model, the local R^2 value was 0.91785, and the adjusted R^2 value was 0.91522. The coefficients of the independent variables in the GTWR model are shown in Figure 3.

Per capita GDP mainly has a negative impact on the tourism eco-efficiency of cities in the Beijing–Tianjin–Hebei region. Except for Beijing, Zhangjiakou, and Chengde, the regression coefficients of other cities are all negative. The cities with highly negative values are mainly Baoding and Cangzhou, which border Beijing and Tianjin, respectively, followed by Hengshui, Xingtai, and Handan in the southern area. This indicates that, due to high emissions and high energy consumption, the level of the green growth of the tourism economics in the southern area is low, and it is still found on the left of the environmental Kuznets curve. Along with the growth of GDP per capita, there are still significant challenges in environmental governance. Therefore, the value of tourism eco-efficiency is low.

The impact of the number of patent grants on tourism eco-efficiency in each city is mainly positive. The positive effects were strongest in Qinhuangdao, Shijiazhuang, and Baoding, while negative effects were strongest in Tianjin, Zhangjiakou, Chengde, and Cangzhou. Technological advancements can assist with the ecological environment protection of tourist destinations, resource utilization efficiency improvements, provide elements of marginal output efficiency enhancements, and enhance tourist eco-efficiency promotion. Otherwise, the negative impact of the number of patent grants on tourism eco-efficiency in some cities can be explained by the lack of government support for the technological progress of tourism. Since tourism involves a wide range of fields, technological progress should penetrate into the production, operation, management, and service of other related industries.

The proportion of urban population in the total population was positively correlated with tourism eco-efficiency, which is consistent with the research results of Zhang et al. [13]. The city with the strongest positive influence was Cangzhou, and the surrounding cities of Cangzhou, Baoding and Xingtai, also had a strong influence. The process of urbanization prompts local governments to increase capital expenditure to upgrade urban public facilities and advocate for green production, green lifestyles, and green consumption modes, which benefits the growth of tourism. Qinhuangdao, Zhangjiakou, Tangshan, and Shijiazhuang are major cities with a strong negative influence. This is mostly due to the fact that the process of urbanization causes huge stress on the natural environment, causing an increase in pollution emissions, resource shortages, and the destruction of resources and the environment caused by urban construction.

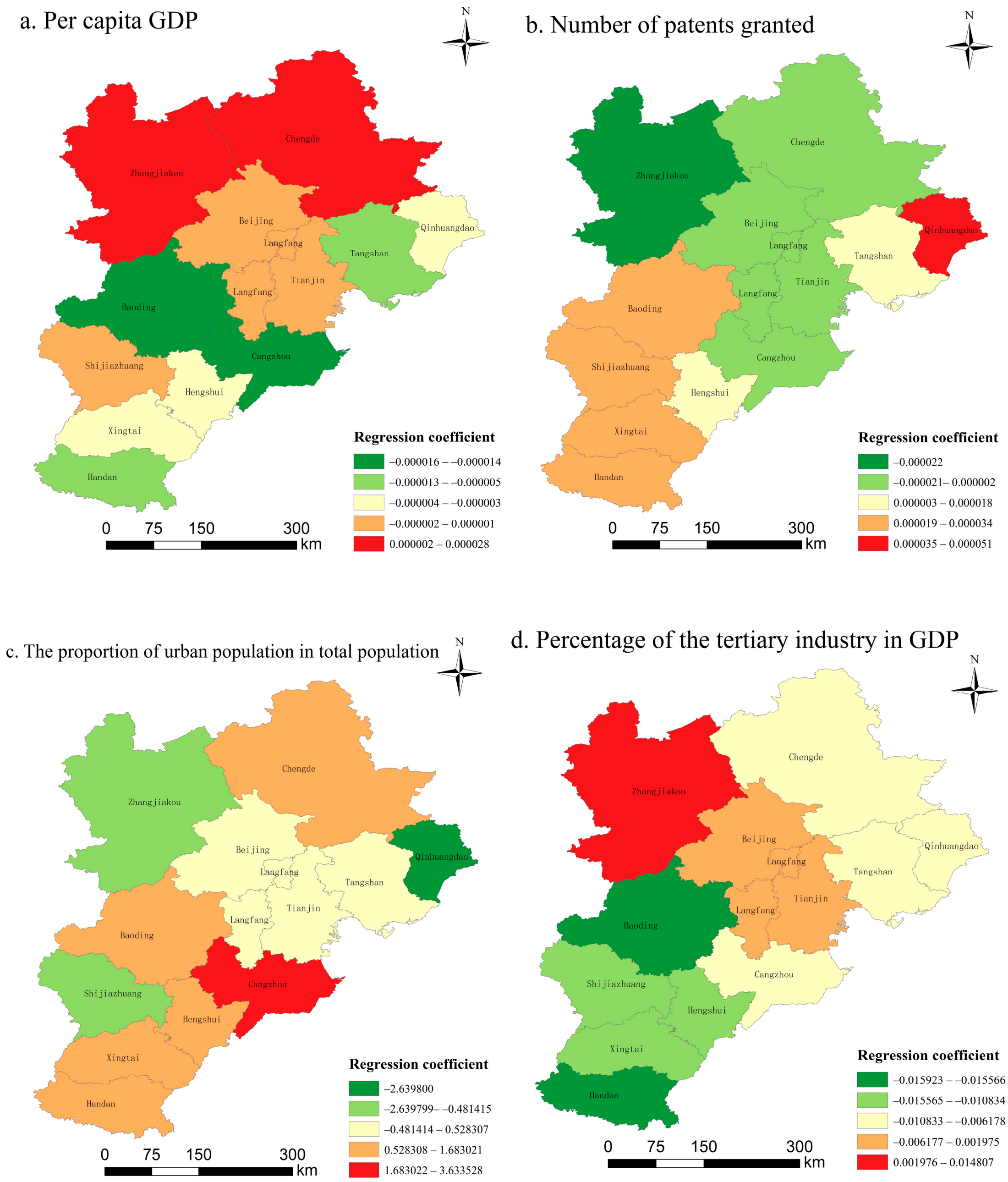

Figure 3. Results of the GTWR analysis of the variables affecting tourism eco–efficiency.

Except for Tianjin and Zhangjiakou, the proportion of tertiary industry in GDP has a negative effect on tourism eco-efficiency in other cities. This negative high-value area is mainly located in the southern area. The principal reason is that the cities in the southern area are dominated by traditional industries, while the modern service industry is less developed. As a result, a changing industrial structure will not immediately enhance tourism eco-efficiency.

4. Conclusions and Discussion

4.1. Conclusions

Combining the super-efficiency SBM-DEA model, GML index, Theil index, and GTWR model, the study evaluated the tourism eco-efficiency of 13 cities in the Beijing–Tianjin–Hebei region, and analyzed their dynamic evolution characteristics and the regional differences.

Through the evaluation method, it can be concluded that tourism eco-efficiency in the Beijing–Tianjin–Hebei region is at a relatively low level, but showed a fluctuant increasing tendency. The mean value of tourism eco-efficiency greatly varies in the region, and the top three cities are Beijing, Tianjin, and Langfang, respectively. The tourism eco-efficiency of cities in Hebei Province is growing significantly faster than for Beijing and Tianjin. Regarding decomposition efficiency, pure technical efficiency outperformed scale efficiency in most cases. The region's tourism eco-efficiency demonstrated a significant polarization; however, there is still significant space for improvement.

According to the GML index analysis, tourism eco-efficiency in the Beijing–Tianjin–Hebei region is influenced by technological efficiency and technological progress. The average growth rates of technological efficiency and technological progress are 9.2% and 11.7%, respectively. It can be inferred that resource allocation and management capabilities should be enhanced in the tourism industry, and a good interactive relationship needs to be formed between the scale of the tourism economy and technological progress.

Based on the Theil index analysis, the regional differences in tourism eco-efficiency tend to be reduced. According to the decomposition difference results, the inter-regional differences in tourism eco-efficiency in the three areas are higher than the intra-regional differences. Therefore, inter-regional difference is the primary factor affecting the tourism eco-efficiency in the Beijing–Tianjin–Hebei region.

With regard to the influencing factors of tourism eco-efficiency, GDP per capita, the proportion of the tertiary industry in GDP, the number of patents granted, and the proportion of urban population in the total population passed the significance test and collinearity diagnosis. These are key determinants of tourism eco-efficiency in the region.

4.2. Limitations and Future Scope of the Study

This study has some limitations. Considering the availability of data, 13 cities in the Beijing–Tianjin–Hebei region were selected as the research objects. Future research should approach this topic on a countywide scale, which may be helpful for further grasping the improvement in tourism eco-efficiency in the Beijing–Tianjin–Hebei region. At the same time, tourism carbon emissions will be included in the undesirable output indicators, which will make the calculation of tourism ecological efficiency more accurate.

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