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The Spatiotemporal Characteristics and Driving Factors of Regional Ecological Efficiency in the Tourism Sector

Gang Deng [1] **and Hsing Hung Chen** [2,*]

[1] The Institute for Sustainable Development, Macau University of Science and Technology, Taipa 999078, Macao; 3220003343@student.must.edu.mo
[2] School of Business, Macau University of Science and Technology, Taipa 999078, Macao
* Correspondence: hhchen@must.edu.mo

Abstract: Improving tourism's ecological efficiency and facilitating harmony between tourism development and the ecological environment are profitable and conducive to sustainable development. In this study, we investigated the relationship between tourism's eco-efficiency for sustainable tourism development and environmental protection by incorporating unexpected outputs to calculate tourism's eco-efficiencies, analyzing the three-dimensional spatial variation and, finally, considering the effects of nine comprehensive factors on the extent of the spatial variation in tourism efficiencies: economic development, openness, social consumption, the digital economy, transportation infrastructure, government intervention, technological innovation, energy consumption, and passenger turnover. First, an unexpected slack-based measure model was applied to calculate the tourism ecological efficiencies of 21 cities in Guangdong Province from 2009 to 2021. Second, the natural breakpoint method and trend surface analysis were used to identify the spatiotemporal differences in and spatial trends of these tourism ecological efficiencies. Finally, the geographical detector model was utilized to analyze the elements affecting the spatial and temporal differences in the tourism ecological efficiencies. Overall, the tourism ecological efficiencies of 21 cities in Guangdong Province are at a high level, showing obvious spatiotemporal changes. Compared with 2009 and 2021, the overall tourism ecological efficiencies of 21 cities in Guangdong Province shifted from a trend of high in the north, low in the south, low in the west, and high in the east to a trend of low in the north, low in the south, high in the west, and low in the east. The distribution in the north–south and east–west directions is in a "U" shape, and the spatial differences in the north–south and east–west directions are relatively significant. We suggest considering the roles of factors such as the development of the digital economy, the level of government intervention, the level of technical innovation, the driving force of transportation, the standard of the transportation infrastructure, and the standard of social consumption. This study provides a constructive approach to elevating the tourism ecological efficiencies of 21 cities in Guangdong Province with regards to the nine driving factors.

Keywords: tourism superefficiency; tourism ecological efficiency; spatiotemporal characteristics; driving factors

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Citation: Deng, G.; Chen, H.H. The Spatiotemporal Characteristics and Driving Factors of Regional Ecological Efficiency in the Tourism Sector. *Sustainability* **2024**, *16*, 982. https://doi.org/10.3390/su16030982

Academic Editor: Wadim Strielkowski

Received: 27 October 2023
Revised: 6 December 2023
Accepted: 11 December 2023
Published: 23 January 2024

1. Introduction

Improving regional tourism's ecological efficiency is conducive to realizing the sustainable development of the tourism industry. With the realization of economic globalization, the scope of economic tourism activities is gradually expanding, and the interactions of ecological tourism activities between regions are becoming more closely intertwined. The environmental pollution caused by tourism activities restricts the sustainable development of the tourism industry. Sustainable tourism development is a focal point in tourism ecology and international tourism geography research, and there is an inseparable relationship between the development of the tourism industry and the construction of ecological civilization. Sustainable tourism development also affects the implementation of land planning and tourism ecological development policies in countries and regions around the world. The report of the 20th National Congress of the Communist Party of China proposes that economic growth should accelerate the transformation of the development pattern, be more focused on improvements in the quality and standard of development, and coordinate the promotion of carbon reduction, pollution reduction, and green expansion and growth, prioritizing ecology and intensifying conservation, as well as green and low-carbon development. Guangdong Province is an important region for the promotion of the implementation of the "Guangdong-Hong Kong-Macao Great Bay Area Cultural and Tourism Development Programme" and the "Guangdong Province Action Plan for Promoting the Construction of World-class Tourism Destinations in Guangdong-Hong Kong-Macao Great Bay Area". In 2021, tourism accommodation units in Guangdong Province received nearly 257.01 million overnight tourists, a year-on-year increase of 11.46% (these data were sourced from the Guangdong Statistical Information Network). In recent years, tourism development in Guangdong Province has shown a growth trend. However, in the process of the sustainable development of the tourism industry, the problem of environmental pollution has become increasingly serious. Guangdong Province has a large population in relation to the nation as a whole, creating significant economic benefits. It is also a transit station for cross-border tourism, and its degree of climate change is quite severe. According to the "Progress Assessment Report on National Low Carbon City Pilot Work" released by the Ministry of Ecology and Environment at the main event of "National Low Carbon Day" in 2023, as of the end of 2022, the cumulative transaction volume of carbon emission quotas in Guangdong Province was 214 million tons, with a transaction amount of CNY 5.64 billion, ranking first in the national regional-carbon-market pilot.

According to the Statistical Bulletin on National Economic and Social Development of Guangdong Province in 2022, by the end of 2022, the permanent population of Guangdong Province was 126.568 million, and it achieved a regional GDP of CNY 12,911.858 billion, which is an increase of 1.9% compared to the previous year. This indicates that Guangdong Province has large amounts of carbon emissions and other gas emissions, as well as severe environmental pollution, and it is under significant pressure to protect its ecological tourism environment. Therefore, it was reasonable to calculate the tourism ecological efficiencies of 21 cities in Guangdong Province with unexpected outputs and analyze the problems and influencing factors in the sustainable development of urban tourism to apply the sustainable development concept, thereby realizing high-quality tourism development. Guangdong Province is geographically close to Hong Kong and Macao. Accelerating the digital, intelligent, and green reform of traditional industries, enhancing the level of industrial digitization and digital industrialization, and promoting the deep integration of digital technologies with the real economy, such as the Internet, big data, and artificial intelligence, as well as, in particular, promoting the deep integration and development of the digital economy and ecological economy, are of great significance for promoting the construction of an ecological civilization. While building world-class tourism destinations in the Guangdong–Hong Kong–Macao Greater Bay area, attention needs to be paid to a series of resource and environmental issues. This will not only help to achieve the coordination between tourism economic growth and the environment, but will also contribute to the sustainability and efficiency of Guangdong's tourism industry and the sustainable development of the external economy.

The development of ecotourism can promote ecological environmental protection, create employment opportunities for local people, achieve the sustainable utilization of local resources, reduce climate pollution and, ultimately, achieve sustainable tourism development [1]. Ecotourism refers to travel to areas with natural resources, such as mountains, rivers, and forests, while considering the sustainability of the natural resources, protection of the local environment, and the promotion of the non-material benefits for residents. Qian Chen and Wanxu Chen et al. found that the tourism development efficiency of the Yangtze River Delta was at the middle level, and that the tourism-development efficiency of the Yangtze River Economic Belt was significantly affected by policies [2].

Measuring tourism efficiency is one of the methods used to evaluate whether the least amount of tourism input resources produces the maximum number of benefits. With the emergence of imbalanced development in the tourism industry, improvements in tourism efficiency can be used to achieve the efficient utilization of tourism resources and, ultimately, the goal of sustainable development. Zhenjie Liao and Lijuan Zhang found that there is a significant clustering phenomenon in the overall difference between tourism's environmental efficiencies in China, and that the clustering level is gradually tending towards optimal [3]. Moreover, there is currently a lack of research on the measurement of the interactions and degrees of influence of the comprehensive factors that affect the spatial differences in tourism efficiencies. Zhoufei Li and Huiyue Liu believe that China's tourism industry is showing a clustering trend with gradient differences, and industrial clustering could significantly improve the overall efficiency [4]. Hongwei Liu and Chenchen Gao et al. found that regional differences and spatial spillover effects affect the carbon-emission-efficiency standard of China's tourism industry [5]. To achieve the sustainable development of the tourism industry, it is necessary to consider both economic and ecological factors. Energy consumption and carbon emissions are crucial for sustainable tourism development, and sustainable tourism development has spatial effects on surrounding cities, which interact with each other. Zhang Hao and Duan Ye et al. concluded that the ecological efficiency of tourism in the Yellow River Basin shows an upward trend over time [6]. Jianping Zha and Wenwen Yuan et al. argue that China's tourism ecological efficiency has improvement potential and exhibits obvious spatial characteristics. The transformation of ecological productivity has had a promoting effect on the growth of the tourism industry, which is weakening [7]. Ecological and environmental factors play a crucial role in the sustainable development of the tourism industry. Studying low-carbon tourism and spatial effects could help to improve the local ecological environment and achieve the sustainable development of the tourism economy [8]. The improvement in ecotourism efficiency could enhance the utilization efficiency of ecotourism resources [9], reduce conflicts among local residents, and encourage tourism departments to consider the local tourist-carrying capacity and strengthen the planning of ecological tourism resources, which can be used to achieve sustainable tourism development [10].

To sum up, most of the research on the spatial differences and influencing factors of tourism's ecological efficiency is at the provincial level, while the relevant research on prefecture-level cities is relatively sparse. Most of the literature uses global and local spatial autocorrelation and cold- and hot-spot analyses, while three-dimensional trend surface analysis to describe the evolution in space and time is rarely used. The indicators used to measure the influencing factors of the spatial differences in tourism's ecological efficiency are not comprehensive. In this study, we used an unexpected-output SBM model to measure the tourism ecological efficiencies of 21 cities in Guangdong Province, and we added spatial-trend surface analysis to describe the spatial differences among them. Finally, a comprehensive evaluation of the factors that affect tourism ecological efficiency was conducted using the geographic detector model, with the aims of promoting the coordinated development of the tourism economy, resources, and environment in Guangdong Province, achieving the sustainable development of the tourism industry, and better promoting the realization of the regional ecological and environmental protection objectives. Slack-based models are among the most commonly used methods because they incorporate unexpected outputs, consider environmental pollution factors, and lay the foundation for sustainable environmental development. The natural discontinuity method and spatial-trend surface analysis are commonly used spatial-analysis methods. We chose the geodetector model because it can be used to analyze the interactions between the driving factors in more detail, rather than simply listing a few impact coefficients. There is a lack of research that comprehensively combines tourism with sustainable development to list relevant suggestions. This study proposes relevant measures from the perspectives of sustainable cultural-tourism-dissemination channels, the development of sustainable tourism products, and the sustainable planning and management of tourist reception and facilities.

Furthermore, the article provides a deeper explanation of the reasons and summarizes the characteristics of the region, as well as local tourism-planning policies, the sustainable development of the tourism economy, and tourism resources and the environment.

2. Research Methods

2.1. Evaluation System of Regional Tourism Ecological Efficiencies

The following is the efficiency-indicator system for tourism development. The data were sourced from the EPS database and the statistical yearbooks of various prefecture-level cities in Guangdong Province. Tourism eco-efficiency is the ratio of inputs to outputs of the tourism-related elements in the tourism production units. In this study, the tourism eco-efficiency indicators of 21 cities in Guangdong Province were categorized into input and output indicators, with the input indicators as the cost indicators, the expected-output indicators as the income indicators, and the unexpected-output indicators as the pollution indicators. Referring to previous studies, the table of the tourism eco-efficiency evaluation index system of 21 cities in Guangdong Province was constructed based on the availability of data and the constraints of the input and output indicators (one-third of the number of DMUs $\geq$ number of indicators) required by the model. As shown in Table 1, the number of employees in the tertiary industry was chosen as the labor input, the number of accommodation and catering enterprises was chosen as the capital input, the internal expenditure on R&D funding was chosen as the technological input, and the proportion of the electricity consumption was multiplied by the tourism income.

Table 1. Efficiency-indicator system for tourism development in 21 cities of Guangdong Province.

Indicator Category	Primary Index	Secondary Indicator	Unit
Input	Labor factor	Employment in the third industry	Ten thousand people
	Capital factor	Number of accommodation and catering companies	Individual
	Technical factor	Internal expenditure of R&D funds	CNY 10,000
	Energy factor	Power consumption	100 million kilowatt hours
Output	Expected output	Number of overnight tourists	10,000 person-times
		Tourism income	CNY billion
	Unexpected output	Tourism sewage discharge	%

Data sources: EPS database and statistical yearbooks of cities in Guangdong Province.

2.2. Research Method

This study was divided into three parts: the calculation of the tourism eco-efficiencies, the process of their spatial variation, and the analysis of the roles of the drivers. Based on this, three hypotheses were proposed: (1) from 2009 to 2021, there were significant spatial differences in the tourism ecological efficiencies among 21 cities in Guangdong Province; (2) the interaction of two driving factors on the tourism efficiency is greater than that of a single influencing factor; (3) technological innovation, digital economy factors, and transportation infrastructure need to be given more attention, while the other driving factors remain unchanged.

2.2.1. SBM-DEA Model

In the process of sustainable economic tourism development, economic production activities consist of expected and unexpected outputs. If the unexpected output is ignored, then the results of the econometric analysis will not truly and effectively reflect the actual development of the region [11]. In this study, we selected the SBM (slack-based measure) unexpected-output (non-radial) model to estimate the tourism superefficiencies of 21 cities in Guangdong Province to achieve greater output with minimal tourism investment [12]. The mathematical expression is as follows:

$$\min\rho = \begin{cases} \dfrac{1 + \frac{1}{m}\sum_{t=1}^{m}\frac{s_i^-}{x_{ik}}}{1 - \frac{1}{q_1 + q_2}\left(\sum_{s=1}^{q_1}\frac{s_r^+}{y_{rk}} + \sum_{t=1}^{q_2}\frac{s_t^{z-}}{z_{tk}}\right)} \\ X\lambda \le x_k - s^-, \\ Y\lambda \le y_k + s^+, \\ Z\lambda \le z_k - s^{z-}, \\ \text{s.t. } \frac{1}{q_1 + q_2}\left(\sum_{s=1}^{q_1}\frac{s_r^+}{y_{rk}} + \sum_{t=1}^{q_2}\frac{s_t^{z-}}{z_{tk}}\right) > 0; \qquad s^-,\ s^+,\ \lambda > 0, \\ i = 1,\ 2,\ \ldots,\ m;\ s = 1,\ 2,\ \ldots,\ q_1;\ t = 1,\ 2,\ \ldots,\ q_2;\ j = 1,\ 2,\ \ldots,\ n,\ (j \ne k), \end{cases} \tag{1}$$

In the formula, the DMUs of the tourism superefficiencies of 21 cities in Guangdong Province are n, the input variable of the tourism ecological efficiencies of 21 cities in Guangdong Province is x, the expected output is y, and the unexpected output is z; s^-, s^+, s^{z-} are the relaxation variables of the input, expected output, and unexpected output, respectively; ρ indicates the tourism ecological efficiency of the evaluation unit ($\rho > 0$).

2.2.2. The Natural Breakpoint Method

The natural breakpoint method is a way of classifying statistical values and grading distribution rules that can maximize the similarities and differences between classes. Therefore, discontinuous points are good boundaries for division and classification, as well as for highlighting more significant spatial differences in tourism ecological efficiencies [13].

2.2.3. Trend Surface Analysis

The trend surface was used to analyze the overall spatial distribution characteristics of the tourism superefficiencies, as well as the differences in the three-dimensional spatial-trend surfaces for depicting the tourism ecological efficiencies. If $Z_i(x_i, y_i)$ is a certain efficiency type of a prefecture-level city (i), (x_i, y_i) is the spatial coordinate, and we can determine the following:

$$Z_i(x_i, y_i) = T_i(x_i, y_i) + \varepsilon_i \tag{2}$$

where $Z_i(x_i, y_i)$ is a trend function [14], representing the object value of the whole region. The trend function can be represented as follows: $T_i(x_i, y_i) = \beta_0 + \beta_1 x + \beta_2 y + \beta_3 x^2 + \beta_4 y^2 + \beta_5 xy$. The ε_i is the autocorrelation random error.

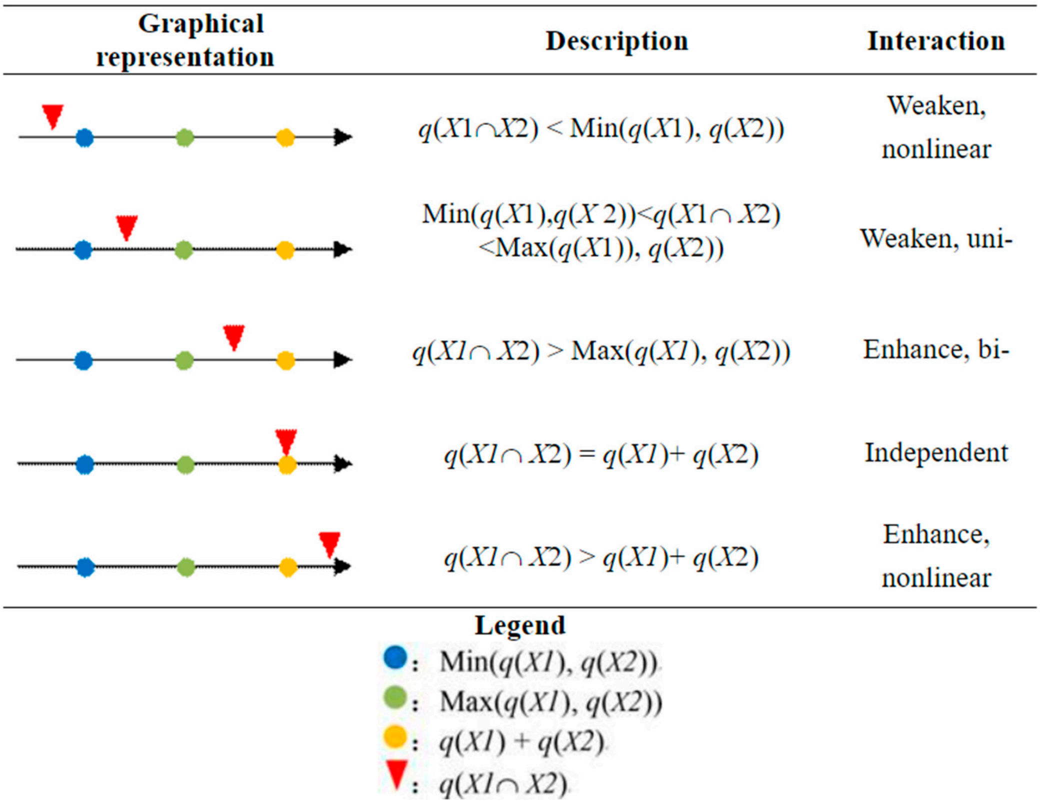
2.2.4. The Geographical Detector Model

The geographical detector model is a method to detect and explain spatiotemporal differentiation, providing a more detailed explanation of the interactions and explanatory powers of various driving and influencing factors. It can be used to study the effects of the explanatory elements on explained elements. The premise of the similarity between scatter of independent elements and that of dependent elements in space is that the independent elements have crucial driving effects on the dependent elements.

$$P = 1 - \frac{1}{\sigma^2}\sum_{h=1}^{L} N_h {\sigma_h}^2 \tag{3}$$

where P is the detection-power value of the detection factor (X). The greater the impact of the detection factor on the spatial differentiation of tourism ecological efficiencies, the higher the *p*-value. The total Y is composed of L layers (the value of h is 1, 2, . . ., L), the layers of the independent element (X) and dependent element (Y) are L, the variance in the tourism ecological efficiency of the first-level research unit is σ^2, and the variance in the tourism-development efficiency of the secondary research unit (sub-regional level (h)) is ${\sigma_h}^2$. The N and N_h are the unit quantities of the whole area and the layer (h), respectively.

Interaction detection is used to estimate whether two influencing factors (X_1 and X_2) will add to or subtract from the interpretation of the dependent element (Y). The evaluation measure is used to compare the value of a single factor and double factor (q) and then analyze the direction and mode of the interaction between the two factors. The interaction force of the two detection factors can be divided into five types, as shown in Figure 1 [15].



Graphical representation	Description	Interaction
	$q(X1 \cap X2) < \mathrm{Min}(q(X1), q(X2))$	Weaken, nonlinear
	$\mathrm{Min}(q(X1), q(X2)) < q(X1 \cap X2) < \mathrm{Max}(q(X1), q(X2))$	Weaken, uni-
	$q(X1 \cap X2) > \mathrm{Max}(q(X1), q(X2))$	Enhance, bi-
	$q(X1 \cap X2) = q(X1) + q(X2)$	Independent
	$q(X1 \cap X2) > q(X1) + q(X2)$	Enhance, nonlinear

Figure 1. Interaction between explanatory variables (X_s). Image source: Wang Jinfeng "Principles and Prospects of The Geographical Detector Model".

3. Results and Discussion

3.1. Analysis of Regional Tourism Ecological Efficiencies

In this study, we adopted the non-radial SBM with variable returns to scale from the perspective of the input, used MAXDEA Ultra 9.0 to estimate the values of the tourism ecological efficiencies, and estimated the average values of each year and region.

As can be seen in Table 2, the tourism superefficiency of Guangzhou city decreased from 2.047 to 1.501 during the research period from 2009 to 2021. During this period, the tourism superefficiency of Guangzhou city was in an effective state and had a stable growth trend, but it began to decrease in 2020. The tourism ecological efficiency of Shenzhen city increased from 1.082 to 1.171 and was in an effective state, with an overall growth trend and a slight declining trend from 2018. The tourism ecological efficiency of Zhuhai city decreased from 1.384 to 1.144, both in an effective state, showing a downward trend on the whole, with a slight decline and an upward trend [16] in 2018 and 2020, respectively. Shantou city's tourism ecological efficiency decreased from 0.863 to 0.615 and was in an effective state from 2010 to 2019, but not in 2009, 2020, or 2021. The tourism ecological efficiency of Foshan city increased from 0.604 to 0.710 and showed an increasing trend in 2009–2018 and a declining trend in 2018–2021. It was not in an effective state in 2009, 2010, or 2021, but it was in the other years. The tourism ecological efficiency of Shaoguan city decreased from 1.152 to 0.717, showing a downward trend on the whole. It did not have an ineffective status in 2011, 2012, 2013, 2020, or 2021, but it did in the other years. The tourism ecological efficiency of Heyuan city decreased from 1.273 to 0.726, showing a downward trend on the whole. It turned from 2017 and then tended to decline. It was not effective in 2020 and 2021 but it was in the other years. The tourism ecological efficiency of

Meizhou city decreased from 1.293 to 1.034, showing a trend of first increasing and then decreasing, and then a turning point and a decline in 2019, all in an effective state. Huizhou city's tourism ecological efficiency increased from 0.847 to 1.059, showing an overall growth trend. It was not effective in 2009, 2010, or 2011 but it was in the other years. The tourism ecological efficiency in Shanwei city decreased from 3.664 to 1.131, both in an effective state, showing a fluctuating upward trend in 2014–2019, a turning point in 2019, and then a decline. The tourism ecological efficiency of Dongguan city decreased from 1.350 to 0.768, showing an eventual decline, and then a sudden decline in 2020. It was not effective in 2020 or 2021, but it was in the other years. The tourism ecological efficiency of Zhongshan city increased from 0.672 to 0.721, showing an ultimate decline, a turning point, and then a decline in 2020, and it was in an ineffective state in 2009, 2010, 2020, and 2021 and in an effective state in the other years. The tourism ecological efficiency of Jiangmen city declined from 0.877 to 0.731. It was not effective in 2009, 2013, 2015, 2020, or 2021, but it was effective in the other years. The tourism ecological efficiency of Yangjiang city increased from 1.041 to 1.306, showing a fluctuating upward trend on the whole. It was not effective in 2010, 2015, 2016, or 2017, but it was effective in the other years. The tourism ecological efficiency of Zhanjiang city rose from 1.293 to 1.468, showing a fluctuating and rising trend on the whole, all in an effective state. The tourism ecological efficiency of Maoming city increased from 1.247 to 1.490, showing a fluctuating downward trend, and it began to descend after 2013 and 2014, both in an effective state. The tourism ecological efficiency of Zhaoqing city decreased from 1.739 to 1.067, showing a trend of initial decline and then an increase. It was not effective in 2014–2020, but it was in the other years. The tourism ecological efficiency of Qingyuan city decreased from 1.625 to 1.033, showing a fluctuating downward trend on the whole. It was not effective in 2018, 2019, or 2020 but it was in the other years. The tourism ecological efficiency of Chaozhou city rose from 1.007 to 1.900, showing a fluctuating and rising trend on the whole. It was not effective in 2011, but it was in the other years.

Table 2. Calculation results of tourism ecological efficiencies of 21 cities in Guangdong Province (2009–2021).

Regions	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean Value
Guangzhou	2.047	2.298	2.615	2.735	2.866	2.800	2.860	2.984	3.180	3.538	3.668	1.521	1.501	2.663
Shenzhen	1.082	1.174	1.188	1.312	1.409	1.492	1.474	1.493	1.435	1.374	1.327	1.350	1.171	1.329
Zhuhai	1.384	1.302	1.384	1.382	1.305	1.357	1.355	1.458	1.391	1.090	1.081	1.136	1.144	1.290
Shantou	0.863	1.103	1.013	1.039	1.058	1.096	1.095	1.101	1.109	1.059	1.035	0.698	0.615	0.991
Foshan	0.604	0.556	1.015	1.055	1.146	1.300	1.235	1.226	1.147	1.144	1.139	1.109	0.710	1.030
Shaoguan	1.152	1.092	0.843	0.719	0.848	1.000	1.002	1.004	1.003	1.035	1.018	0.584	0.717	0.924
Heyuan	1.273	1.634	1.681	1.563	1.345	1.222	1.105	1.100	1.071	1.066	1.045	0.727	0.726	1.197
Meizhou	1.293	1.301	1.203	1.579	1.773	1.689	2.367	2.409	2.336	2.440	2.186	1.207	1.034	1.755
Huizhou	0.847	0.907	0.852	1.050	1.064	1.052	1.066	1.041	1.156	1.250	1.362	1.119	1.059	1.063
Shanwei	3.664	2.784	1.640	1.489	1.449	1.497	1.512	1.817	2.309	2.027	2.493	1.116	1.131	1.918
Dongguan	1.350	1.023	1.475	1.207	1.109	1.062	1.381	3.172	2.915	2.774	2.717	0.777	0.768	1.672
Zhongshan	0.672	0.572	1.003	1.058	1.059	1.033	1.052	1.145	1.192	1.410	1.688	0.828	0.721	1.033
Jiangmen	0.877	1.119	1.128	1.015	0.859	1.008	0.839	1.009	1.004	1.049	1.030	0.704	0.731	0.952
Yangjiang	1.041	0.692	1.025	1.052	1.032	1.003	0.873	0.812	0.772	1.093	1.144	1.848	1.306	1.053
Zhanjiang	1.293	2.062	2.957	3.242	2.926	2.132	2.386	1.819	1.832	2.101	2.038	1.519	1.468	2.137
Maoming	1.247	1.197	1.387	1.328	5.860	6.550	3.852	2.220	1.921	1.979	1.780	1.466	1.490	2.483
Zhaoqing	1.739	1.426	1.253	1.175	1.060	0.802	0.804	0.788	0.750	0.736	0.738	0.800	1.067	1.011
Qingyuan	1.625	1.649	1.292	1.069	1.190	1.177	1.100	1.223	1.095	0.878	0.789	0.686	1.033	1.139
Chaozhou	1.007	1.020	0.683	1.061	1.046	1.326	1.141	1.100	1.267	1.323	1.917	2.190	1.900	1.306
Jieyang	1.000	1.374	1.042	1.136	1.351	1.318	1.196	1.867	1.445	1.758	1.838	1.000	1.000	1.333
Yunfu	1.164	1.124	1.220	1.173	1.233	1.415	1.333	1.358	1.220	1.465	1.380	1.295	1.194	1.275
Mean value	1.296	1.305	1.329	1.354	1.571	1.587	1.478	1.531	1.502	1.552	1.591	1.128	1.071	-

In 2009 and 2021, the tourism ecological efficiency of Jieyang city was 1.000, in an effective state in both years, showing a fluctuating and rising trend on the whole. The tourism ecological efficiency of Yunfu city increased from 1.164 to 1.194, showing a decline, all in an effective state. To sum up, the tourism ecological efficiencies of most of the prefecture-level cities showed downward trends in 2020 and 2021 [17]. The reason for this may be that, in 2019, COVID-19 broke out globally, and tourism was severely damaged. However, Zhuhai city's tourism ecological efficiency did not show a downward trend in 2020. The reason for this may be that Zhuhai city is close to the Macao Special Administrative Region, and Macao's tourism policies closely followed those of the mainland in 2020–2021, with frequent exchanges with the mainland [18]. Moreover, Macao is nowhere near as isolated from the mainland as Hong Kong and foreign countries [19].

It can be concluded that the tourism ecological efficiencies of Shenzhen city, Zhuhai city, Guangzhou city, Meizhou city, Zhanjiang city, Maoming city, Jieyang city, and Yunfu city are all in an effective state. Compared with 2009 and 2021, Shanwei city and Chaozhou city had the largest changes in their tourism ecological efficiencies, with a decrease of 2.533 and an increase of 0.893, respectively, while Zhaoqing city and Qingyuan city had the second largest changes, with decreases of 0.672 and 0.592, respectively. The tourism ecological efficiencies of Shenzhen city, Huizhou city, Foshan city, Zhongshan city, Yangjiang city, Zhanjiang city, Maoming city, Yunfu city, Jieyang city, and Chaozhou city show increasing trends.

Shenzhen city is one of the first cities in the country in which the development of the cultural and tourism industries was encouraged by the state council. Shenzhen city has taken advantage of the first-mover advantage of the new technology to vigorously promote the sustainable development of its cultural industries. Zhongshan city is also committed to strengthening the protection of intangible culture, taking the lead in carrying out "intangible cultural heritage [20] to retain homesickness" in the province. "Work, Zhanjiang city" strives to build a regional tourism demonstration zone to promote the sustainable development of cultural tourism. Chaozhou city has a thousand-year-old city, mountains, rivers, lakes, seas, villages, and red-tourism relics. Yunfu city is striving to build a highland for ecotourism in northern Guangdong and has held a series of rural tourism activities. Jieyang city is the birthplace of Chaoshan culture and is rich in cultural heritage. There are also representative intangible cultural heritage projects [21], with 18 A-level scenic spots. Foshan Zumiao Museum and other museums have been rated as national A-level tourist attractions. Foshan Yongchun Boxing has been successfully selected for the national representative intangible cultural heritage project expansion list, and cultural heritage tourism, intangible cultural heritage tourism, red tourism, food tourism, and industrial tourism have developed rapidly. Huizhou city has vigorously developed homestay tourism, which has promoted the revitalization of rural areas [22] and an improvement in the tourism quality. Shuidong Street has been rated as a provincial tourism and leisure block. Maoming city is a production base of litchi, with a rich litchi culture, as well as many local original cultural and artistic works. Yangjiang city has scenic spots, such as Hailing Island, as well as coastal tourism [23], and it has a good development trend [24].

Overall, Guangzhou city has vigorously strengthened the protection of its immaterial cultural heritage [25] and promoted the sustainable dissemination of Lingnan culture. In recent years, Guangzhou city has reinforced the development of the sustainable cultural industry and strengthened the construction of tourist hotels. The tourism technology in the scenic area of Guangzhou Tower has developed rapidly and was successfully selected for the list of national tourism technology demonstration parks in 2022. Zhuhai city has many island tourism resources, such as the Zhuhai Wanshan Islands and Hengqin International Leisure Tourism Island, which benefit the development of sustainable tourism in Zhuhai city. In recent years, Shanwei city has made every effort to build the best destination for coastal leisure tourism [26] in China and promote the sustainable development of culture, tourism, and sports. Meizhou city is committed to promoting its intangible cultural heritage and exhibition activities, rural tourism, ecological leisure tourism, red tourism, research tourism, etc. It has rich traditional mountain operas and ecological tourism attractions. The

Yunshan Valley Ecological Tourism Area and Pearl Red Sincerity Wine City Tourist Area in eastern Guangdong Province have been rated as national 3A scenic spots. Zhaoqing Yanyang Lake Tourist Resort and Evergrande Century Dream City Tourist Resort have been announced as provincial tourist resorts, and the tourism technology has been well developed. In recent years, Qingyuan city has formulated the "Work Plan for Qingyuan city to Create a Provincial Whole-Territory Tourism Demonstration Zone in Guangdong Province" and actively developed the northern ecocultural tourism cooperation zone. The decline in the tourism ecological efficiency in Shantou city may be due to the need to improve the skills of employees [27] by carrying out skills training, and to promote Shantou city's sustainable tourism resources. The decline in the ecological efficiency in Shaoguan city may be due to the absence of innovation, which is decisive for enriching new tourism formats [28], such as "ecological+" and "health+", even though the city holds a series of cultural and tourism physical activities and feast days. The cause of the decline in the ecological efficiency in Heyuan city may be that the construction of rural homestay projects is still insufficient; the infrastructure, such as accommodation and catering, needs to be improved, and the publicity of rural sustainable cultural brands needs to be stressed. The decline in the tourism ecological efficiency in Jiangmen city may be due to the lack of environmental awareness, resulting in environmental pollution. It is necessary to innovate in the use of new energy and improve the environmental awareness of tourists. Dongguan city is the gathering place of traditional factories, and environmental protection measures need to be improved. The city also needs to improve enterprise environmental protection training and deal with environmental protection problems more effectively.

The following discussion describes the spatial differentiation in the tourism eco-superefficiencies of 21 cities in Guangdong Province from 2009 to 2021.

3.2. Spatiotemporal Differentiation Analysis of Regional Tourism Ecological Efficiencies

The Pearl River Delta region and some eastern and western Guangdong regions, such as Shenzhen, Foshan, Huizhou, Zhongshan, Yangjiang, Zhanjiang, Maoming, Chaozhou, Jieyang, and Yunfu, have the fastest efficiency growth. The slowest efficiency growth occurs in some central regions, such as Heyuan, Shanwei, and Dongguan, while average efficiency growth occurs in some northern Guangdong and Pearl River Delta regions, such as Zhuhai, Shantou, Shaoguan, Meizhou, Jiangmen, Zhaoqing, and Qingyuan. In summary, the city with the fastest efficiency growth is Yangjiang city, with an average annual growth rate of about 1.019. The city with the slowest efficiency growth is Shanwei city, with an average annual growth rate of about 0.907.

In recent years, Yangjiang city has strengthened ecological protection and governance over county-level environmental pollution, guided the green and low-carbon development of the county-level economy, deepened the reform of the county-level ecological environment system, vigorously promoted the treatment of rural domestic sewage, strengthened the treatment of urban and rural black and odorous water bodies, as well as that of agricultural non-point source pollution, focused on ensuring soil environmental safety, and improved the collection, transportation, and disposal systems of household waste in counties, towns, and villages. Some water companies in Shanwei city have improperly treated their wastewater, resulting in pollutants exceeding the standard, such as chromium, nickel, zinc, the chemical oxygen demand, ammonia nitrogen, nitrogen, and phosphorus.

More specifically, it can be seen in Figure 2 that the regions with low tourism superefficiencies in 2009 include Jiangmen city, Foshan city, Zhongshan city, Huizhou city, and Shantou city (0.604000–0.877000), the regions with relatively low tourism ecological efficiencies include Yunfu city, Yangjiang city, Shaoguan city, Shenzhen city, Jieyang city, and Chaozhou city (0.877001–1.164000), and the regions with medium tourism ecological efficiencies include Zhanjiang city, Maoming city, Zhuhai city, Dongguan city, Heyuan city, and Meizhou city (1.164001–1.384000). Zhaoqing city, Qingyuan city, and Guangzhou city (1.384001–2.047000) have relatively high tourism ecological efficiencies, while Shanwei city (2.047001–3.664000) has a high tourism ecological efficiency. In 2015, the regions with low tourism ecological efficiencies included Yangjiang city, Jiangmen city, and Zhaoqing city (0.804000–0.873000), the regions with relatively low tourism ecological efficiencies included Zhongshan city, Qingyuan city, Huizhou city, Shaoguan city, Heyuan city, and Shantou city (0.873001–1.105000), the regions with medium tourism ecological efficiencies included Foshan city, Jieyang city, and Chaozhou city (1.105001–1.235000), the regions with relatively high tourism ecological efficiencies included Yunfu city, Zhuhai city, Dongguan city, Shenzhen city, and Shanwei city (1.235001–1.512000), and the regions with high tourism ecological efficiencies included Zhanjiang city, Maoming city, Guangzhou city, and Meizhou city (1.512001–3.852000). In 2021, the region with low tourism ecological efficiency was Shantou city (0.615000), the regions with relatively low tourism ecological efficiencies included Jiangmen city, Foshan city, Zhongshan city, Dongguan city, Shaoguan city, and Heyuan city (0.615001–0.768000), the regions with medium tourism ecological efficiencies included Zhaoqing city, Qingyuan city, Huizhou city, Meizhou city, and Jieyang city (0.768001–1.067000), the regions with relatively high tourism ecological efficiencies included Yunfu city, Yangjiang city, Zhuhai city, Shenzhen city, and Shanwei city (1.067001–1.306000), and the regions with high tourism ecological efficiencies included Zhanjiang city, Maoming city, Guangzhou city, and Chaozhou city (1.306001–1.900000). Compared with 2009 and 2021, Guangzhou city changed from an area with a relatively high level of tourism ecological efficiency [29] to an area with a high level of tourism ecological efficiency. Shenzhen city changed from an area with a relatively low level of tourism ecological efficiency to an area with relatively high tourism ecological efficiency. Zhuhai city changed from an area with a medium level of tourism ecological efficiency to an area with a relatively high level of tourism ecological efficiency. Shantou city remained a low-tourism-ecological-efficiency area [30]. Foshan city changed from an area with low tourism ecological efficiency area to an area with relatively low tourism ecological efficiency. Shaoguan city maintained a relatively low level of tourism ecological efficiency. Heyuan city transformed from a region with a medium level of tourism ecological efficiency into a region with a relatively low level of tourism ecological efficiency. Meizhou city maintained a medium level of tourism ecological efficiency. Huizhou city transformed from a region with low tourism ecological efficiency into a region with medium tourism ecological efficiency. Shanwei city transformed from a region with high tourism ecological efficiency into a region with a relatively high level of tourism ecological efficiency. Dongguan city changed from a region with medium tourism ecological efficiency to a region with a relatively low level of tourism ecological efficiency. Zhongshan city changed from a region with a low level of tourism ecological efficiency to a region with a relatively low level of tourism ecological efficiency. Jiangmen city changed from a region with a low level of tourism ecological efficiency to a region with a relatively low level of tourism ecological efficiency. Yangjiang city changed from a region with a relatively low level of tourism ecological efficiency to a region with a relatively high level of tourism ecological efficiency. Zhanjiang city changed from an area with medium tourism ecological efficiency to an area with high tourism ecological efficiency. Maoming city changed from an area with medium tourism ecological efficiency to an area with high tourism ecological efficiency. Zhaoqing city changed from an area with a relatively high level of tourism ecological efficiency to an area with medium tourism ecological efficiency. Qingyuan city changed from an area with a relatively high level of tourism ecological efficiency to an area with medium tourism ecological efficiency. Chaozhou city changed from a region with a relatively low level of tourism ecological efficiency to a region with high tourism ecological efficiency. Jieyang city changed from a region with a relatively low level of tourism ecological efficiency to a region with medium tourism ecological efficiency. Finally, Yunfu city changed from a region with a relatively low level of tourism ecological efficiency to a region with a relatively high level of tourism ecological efficiency.

The following discussion introduces the spatial-trend surface analysis of the tourism eco-superefficiencies of 21 cities in Guangdong Province from 2009 to 2021 from a three-dimensional perspective.

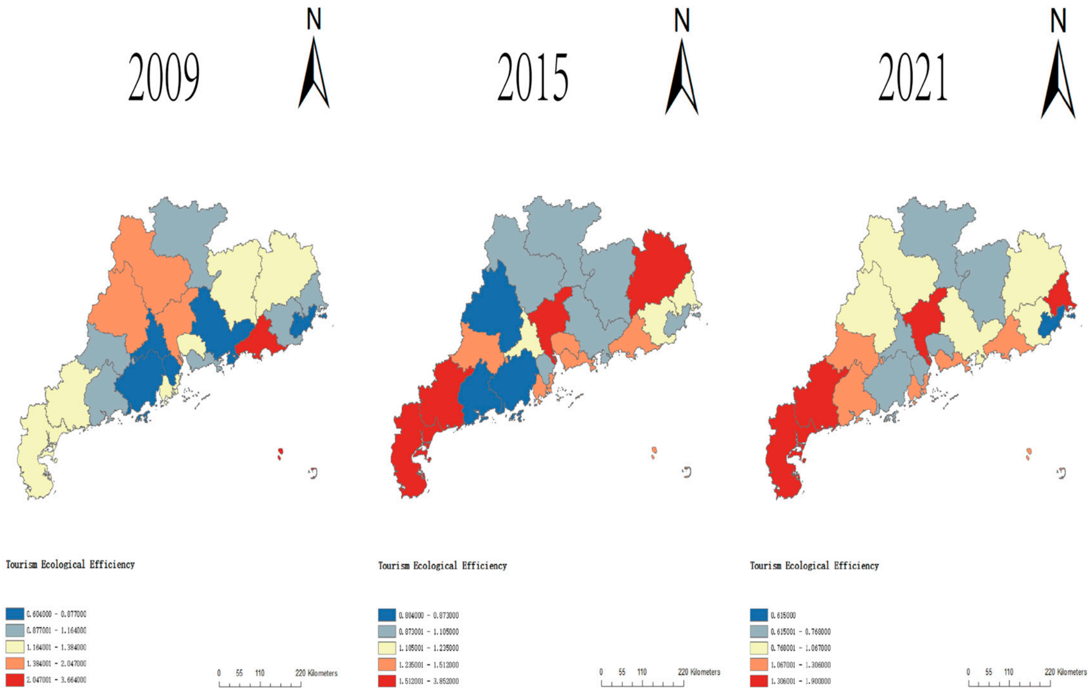


Figure 2. Spatial and temporal differences in tourism ecological efficiencies of 21 cities of Guangdong Province.

3.3. Spatial-Trend Surface Analysis of Ecological Efficiencies in Tourism Sector

It can be seen in Figure 3 that the X and Y axes represent the due east and due north directions separately, and the Z axis is the attribute value of the tourism ecological efficiency. In 2009, the overall tourism ecological efficiency in Guangdong Province tended to be high in the north and low in the south, low in the west and high in the east, flat in the north and south, and flat in the east and west, indicating that the spatiotemporal differentiation of the tourism superefficiencies was stable in the north and west directions. In 2015, the tourism ecological efficiency in Guangdong Province showed a "U" scatter in the north–south direction overall, and a "U" distribution in the east–west orientation. The tourism ecological efficiency presented a trend of high in the west and low in the east and low in the north and high in the south. The difference between the east and west was obvious, showing an increasing trend from the northeast to the southwest. In 2021, the tourism ecological efficiencies in Guangdong Province were generally low in the north, high in the south, high in the west, and low in the east. The "U" pattern is distributed in the east and west, and the trend gradually decreases from the west to the east. The spatiotemporal difference between the north and south is also obvious. Compared with 2009 and 2021, the tourism ecological efficiencies in Guangdong Province generally changed from high in the north and low in the south and low in the west and high in the east to a trend of low in the north and high in the south and high in the west and low in the east. The ecological tourism efficiency in the Pearl River Delta Urban Agglomeration increased, while the ecological efficiency of tourism agencies in northern Guangdong decreased. In addition, both the north–south and east–west directions show a "U" distribution, and the spatial differences between the north–south and east–west orientations are more obvious.

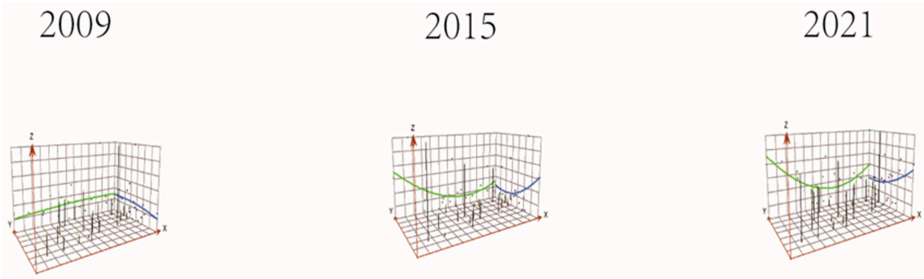


Figure 3. Spatial-trend surface analysis of tourism ecological efficiencies of 21 cities in Guangdong Province.

3.4. Analysis of Factors That Influence Spatiotemporal Differentiation of Regional Tourism Ecological Efficiencies

The explanatory powers of the integrated individual driving influences on the spatial evolution of the tourism eco-superefficiencies of 21 cities in Guangdong Province, the influencing process, and the roles of the integrated individual driving influences are discussed below.

3.4.1. Selection of Interfering Factors

While combining the current tourism-development situations of 21 cities of Guangdong Province, nine factors were selected as the driving factors of the tourism ecological efficiency: economic development, openness, social consumption, the digital economy, transportation infrastructure, government intervention, scientific and technological innovation, energy technology, and transportation. We took the estimated tourism ecological efficiency as the explanatory variable. The GDP per capita indicator is applied to represent the standard of economic development (ED) [31]. The total import and export volume is divided by the regional GDP to illustrate the extent of the opening up (IE) and is converted into RMB at the yearly exchange rate and then divided by the GDP. The total amount of retail sales of retail consumer goods is divided by the regional GDP to represent the level of social consumption (SC), and the total post and telecommunication business volume is divided by the regional GDP to represent the evolution of the digital economy (PT). The highway mileage divided by the administrative area of a prefecture-level city represents the standard of the transportation infrastructure (HM). The sum of the local public revenue and expenditure divided by the regional GDP represents the level of government intervention (PR). The internal expenditure of R&D funds divided by the regional GDP represents the level of technological innovation (ST). The consumption of electricity divided by the GDP represents the level of energy technology (ET) [32], and the passenger turnover represents the driving force (DT) [33], as shown in Table 3.

Table 3. Descriptions of driving-influence factors.

Impact Factors	Representation of Variables	Processing Method
Standard of economic development (ED) Extent of openness to outside world (IE)	GDP per capita (CNY) Total import and export volume (USD 100 million)	GDP per capita Total import and export divided by GDP
Standard of social consumption (SC)	Retail sales of consumer commodities (CNY 100 million)	Retail sales of consumer commodities divided by GDP
Development of digital economy (PT)	Post and telecommunication business (CNY 100 million)	Post and telecommunication business divided by regional GDP

Table 3. *Cont.*

Impact Factors	Representation of Variables	Processing Method
Level of transportation infrastructure (HM)	Highway mileage (km)	Highway mileage/administrative area of prefecture-level cities
Level of government intervention (PR)	Total revenue and expenditure of local public finances (CNY 100 million)	Total revenue and expenditure of local public finance divided by GDP
Extent of technological innovation (ST)	Internal expenditure of R&D funds (CNY 10,000)	R&D internal expenditure divided by GDP
Extent of energy technology (ET)	Power consumption (100 million kilowatt hours)	Electricity consumption divided by GDP
Passenger turnover representing driving force (DT)	Passenger turnover (100 million person-kilometers)	Passenger turnover

3.4.2. Analysis of Detection Results

The geographical detector was applied to study the essential mechanism of the space–time divergence of the tourism ecological efficiencies of the 21 cities in Guangdong Province to explore the scientific path to more reasonably improving the region's tourism ecological efficiencies. The ArcGIS natural discontinuity method was used to divide each driving factor into five categories from low to high, to convert each factor from a numerical quantity to a type quantity, to carry out spatial matching between the tourism ecological efficiencies and each driving factor on the ArcGIS platform, and then to calculate the q value of the effect of each driving factor on the ecological efficiencies in the tourism sector (Table 4).

Table 4. Detection results of factors in impact on tourism ecological efficiency.

Detection Factors	ED	IE	SC	PT	HM	PR	ST	ET	DT
2009 q value	0.142136	0.190912	0.15466	0.12863	0.268459	0.286866	0.151502	0.253571	0.18265
2015 q value	0.059100945	0.53909288	0.325386762	0.083380459	0.118753977	0.368508681	0.078199743	0.586879952	0.280379996
2021 q value	0.189445522	0.239699073	0.065960513	0.107387891	0.153845877	0.055287211	0.46481257	0.166998547	0.42681933

In 2009, the level of government intervention [34], standard of transportation infrastructure [35], level of energy technology, and degree of opening up were the crucial influencing factors for the spatial and temporal differences in the tourism ecological efficiencies in Guangdong Province, with explanatory powers of 0.28686866, 0.268459, 0.253571, and 0.190912, respectively. In 2015, the level of energy technology, degree of opening up, standard of government intervention, and standard of social consumption were the main influencing factors for the space–time difference in the tourism ecological efficiencies in Guangdong Province, with explanatory powers of 0.586879952, 0.53909288, 0.368508681, and 0.325386762, respectively. In 2021, the extent of scientific and technological innovation, transportation driving force, degree of opening up, and standard of economic development [36] were the main influencing factors of the space–time difference in the tourism ecological efficiencies in Guangdong Province, with explanatory powers of 0.46481257, 0.42681933, 0.239699073, and 0.189445522, respectively.

In 2009, the weak influencing factors were the development of the digital economy, the standard of economic development, the level of scientific and technological innovation, and the level of social consumption. In 2015, the weak influencing factors were the standard of economic development, the level of scientific and technological innovation, the development of the digital economy, and the level of transportation infrastructure. In 2021, the weak influencing factors were the level of government intervention, the level of social consumption, the evolution of the digital economy, and the transportation-infrastructure level. These results reveal that the active effects of these factors on the tourism ecological efficiency are not sufficiently obvious.

In Table 5, these results show the relationship between the effects of the interaction between two influencing factors in the tourism ecological efficiency and the impact of each impact factor on the tourism ecological efficiency. It can be concluded that the influence of the interaction between different factors is greater than that of a single effect. Specifically, in 2009, the impact of the ED alone on the tourism ecological efficiency was 0.142136455, and the impact of the IE–ED interaction on the tourism ecological efficiency was 0.298666665, which was greater than the impact of the IE alone (0.190912426). The impact of the SC alone on the tourism ecological efficiency was 0.154659884, which is less than the effects of the SC–ED and SC–IE interactions. The impact of the PT alone on the tourism ecological efficiency was 0.128630097, which was weaker than those of the PT–ED, PT–IE, and PT–SC interactions. The impact of the HM alone on the tourism ecological efficiency was 0.268459064, which was weaker than the effects of the interactions between the HM and ED, HM and IE, HM and SC, and HM and PT. The impact of the PR alone on the tourism ecological efficiency was 0.286865957, which was smaller than those of the PR–ED, PR–IE, PR–SC, PR–PT, and PR–HM interactions. The impact of the PR alone on the tourism ecological efficiency was 0.286865957, which was smaller than those of the PR–ED, PR–IE, PR–SC, PR–PT, and PR–HM interactions. The impact of the ST alone on the tourism ecological efficiency was 0.151501605, which was less than those of the ST–ED, ST–IE, ST–SC, ST–PT, ST–HM, and ST–PR interactions. The impact of the ET alone on the tourism ecological efficiency was 0.253570744, which was smaller than those of the ET–ED, ET–IE, ET– SC, ET–PT, ET–HM, ET–PR, ET–ST interactions. The impact of the DT alone on the tourism ecological efficiency was 0.182650423, which was weaker than the impacts of the DT–ED, DT–IE, DT–SC, DT–PT, DT–HM, DT–PR, DT–ST, and DT–ET interactions.

Table 5. Interaction results between detection factors in 2009.

	ED	IE	SC	PT	HM	PR	ST	ET	DT
ED	0.142136455								
IE	0.298666665	0.190912426							
SC	0.961697031	0.462517778	0.154659884						
PT	0.313250281	0.418535659	0.900427116	0.128630097					
HM	0.830382655	0.842947435	0.88204046	0.838969691	0.268459064				
PR	0.627721515	0.560448473	0.945414927	0.553102773	0.919567373	0.286865957			
ST	0.279792064	0.336245843	0.493327603	0.357902396	0.840454907	0.544588858	0.151501605		
ET	0.516115666	0.556676341	0.519783316	0.571215048	0.966539482	0.605325418	0.502818564	0.253570744	
DT	0.342911129	0.497707846	0.41546602	0.418602713	0.919898717	0.634402544	0.435816618	0.882831865	0.182650423

As shown in Table 6, the impact of the ED alone on the ecological efficiency in the tourism sector is 0.059100945, and the effect on the IE alone on the tourism superefficiency is 0.53909288, which is weaker than the effect of the IE–ED interaction on the tourism ecological efficiency. The effect of the SC alone on the tourism ecological efficiency is 0.325386762, which is weaker than the effects of the SC–ED and SC–IE interactions. The impact of the PT alone on the tourism ecological efficiency is 0.083380459, which is smaller than those of the PT–ED, PT–IE, and PT–SC interactions. The impact of the HM alone on the tourism ecological efficiency is 0.118753977, which is weaker than the effects of the interactions between the HM and ED, HM and IE, HM and SC, and HM and PT. The impact of the PR alone on the efficiency is 0.368508681, which is smaller than those of the PR–ED, PR–IE, PR–SC, PR–PT, and PR–HM interactions. The impact of the ST alone on the tourism ecological efficiency is 0.078199743, which is weaker than those of the ST–ED, ST–IE, ST–SC, ST–PT, ST–HM, and ST–PR interactions. The impact of the ET alone on the tourism ecological efficiency is 0.586879952, which is smaller than those of the ET–ED, ET–IE, ED–SC, ED–PT, ED–HM, and ED–PR interactions. The impact of the DT alone on the tourism ecological efficiency is 0.28037996, which is less than the impacts of the DT–ED, DT–IE, DT–SC, DT–PT, DT–HM, DT–PR, DT–ST, and DT–ET interactions.

Table 6. Interaction results between detection factors in 2015.

	ED	IE	SC	PT	HM	PR	ST	ET	DT
ED	0.059100945								
IE	0.732043796	0.53909288							
SC	0.921325115	0.968896234	0.325386762						
PT	0.362341289	0.793327084	0.919819641	0.083380459					
HM	0.730362743	0.776406543	0.477339983	0.785833379	0.118753977				
PR	0.737920519	0.780607785	0.665578633	0.646084263	0.724880369	0.368508681			
ST	0.4872576 85	0.866182639	0.689911346	0.559901597	0.513419546	0.927160603	0.078199743		
ET	0.854148395	0.888919809	0.88389823	0.851689095	0.861448034	0.950485863	0.939006916	0.586879952	
DT	0.540963862	0.865563424	0.528458914	0.572582716	0.836959585	0.480333787	0.877368148	0.797140573	0.280379996

In Table 7, the effect of the ED alone on the efficiency in the tourism sector is 0.189445522, and the effect of the IE alone on the efficiency is 0.239699073, which is less than the impact of the IE–ED interaction on the tourism ecological efficiency. The impact of the SC alone on the efficiency is 0.065960513, which is weaker than the effects of the SC–ED and SC–IE interactions. The impact of the PT alone on the tourism ecological efficiency is 0.107387891, which is smaller than those of the PT–ED, PT–IE, and PT–SC interactions. The impact of the HM alone on the tourism ecological efficiency is 0.153845877, which is less than the effects of the interactions between the HM and ED, HM and IE, HM and SC, and HM and PT. The impact of the PR alone on the efficiency is 0.055287211, which is smaller than those of the PR–ED, PR–IE, PR–SC, PR–PT, and PT–HM interactions. The impact of the ST [37] alone on the tourism ecological efficiency is 0.46481257, which is weaker than those of the ST–ED, ST–IE, ST–SC, ST–PT, ST–HM, and ST–PR interactions. The impact of the ET alone on the tourism ecological efficiency is 0.166998547, which is smaller than those of the ET–ED, ET–IE, ET–SC, ET–PT, ET–HM, and ET–PR interactions. The impact of the DT alone on the tourism ecological efficiency is 0.42681933, which is weaker than the impacts of the DT–ED, DT–IE, DT–SC, DT–PT, DT–HM, DT–PR, DT–ST, DT–ET interactions.

To sum up, in Tables 5–7, it can be seen that the effects of the interaction of two influencing factors on the spatial distribution of the tourism ecological efficiencies in Guangdong Province are superior to [38] the effects of single influencing factors.

Table 7. Interaction results between detection factors in 2021.

	ED	IE	SC	PT	HM	PR	ST	ET	DT
ED	0.189445522								
IE	0.549558921	0.239699073							
SC	0.548388248	0.732994908	0.065960513						
PT	0.406013823	0.774539171	0.704856291	0.107387891					
HM	0.576533135	0.765628438	0.491348719	0.457798958	0.153845877				
PR	0.389172451	0.79636637	0.315100797	0.32445565	0.38694676	0.055287211			
ST	0.764842567	0.705360941	0.871932626	0.871851366	0.767610493	0.849410081	0.46481257		
ET	0.341565774	0.584189411	0.300402996	0.756568758	0.470541375	0.524187979	0.699599583	0.166998547	
DT	0.734937981	0.812191885	0.930883697	0.76652778	0.866207598	0.568767437	0.785601471	0.788894218	0.42681933

As shown in Table 8, there are two interplay types for each influencing factor include: the two-factor-enhanced type and the nonlinear-enhanced type. Specifically, in 2009, the effect of the interaction of the transportation infrastructure level (HM) [39] and other factors on the tourism ecological efficiency produced the nonlinear enhancement effect, while the interaction of other factors produced the two-factor-enhancement effect, but the interaction was not as significant as that of the nonlinear enhancement effect, indicating that the interaction of the transportation infrastructure level in the promotion of the tourism ecological efficiency should be noted. According to Table 5, the explanatory powers of the mutual interactions between the energy-technology standard (ET) and transportation-infrastructure level (HM), social consumption level (SC) and economic development level (ED), government intervention level (PR) and social consumption level (SC), and traffic driving force (DT) and transportation-infrastructure level (HM) [40] are in the top four of all the interaction factors. In 2009, the efficiencies in the tourism sector in Guangdong Province were inseparable from the energy-technology level, transportation-infrastructure level, social consumption level, economic development level, government intervention level, transportation driving force, and other factors. The comprehensive interaction between these factors could significantly promote the increase in the efficiencies in the tourism sector in Guangdong Province.

Table 8. Types of interaction between detection factors during study period.

Detection Factors	Types of Interactions in 2009	Types of Interactions in 2015	Types of Interactions in 2021
ED∩IE	Bi	Nonlinear	Nonlinear
ED∩SC	Nonlinear	Nonlinear	Nonlinear
ED∩PT	Bi	Nonlinear	Nonlinear
ED∩HM	Nonlinear	Nonlinear	Nonlinear
ED∩PR	Nonlinear	Nonlinear	Nonlinear
ED∩ST	Bi	Nonlinear	Nonlinear
ED∩ET	Nonlinear	Nonlinear	Bi
ED∩DT	Bi	Nonlinear	Nonlinear
IE∩SC	Nonlinear	Nonlinear	Nonlinear
IE∩PT	Nonlinear	Nonlinear	Nonlinear
IE∩HM	Nonlinear	Nonlinear	Nonlinear
IE∩PR	Nonlinear	Bi	Nonlinear
IE∩ST	Bi	Nonlinear	Bi
IE∩ET	Nonlinear	Bi	Nonlinear
IE∩DT	Nonlinear	Bi	Nonlinear
SC∩PT	Nonlinear	Nonlinear	Nonlinear
SC∩HM	Nonlinear	Bi	Nonlinear
SC∩PR	Nonlinear	Bi	Nonlinear
SC∩ST	Nonlinear	Nonlinear	Nonlinear
SC∩ET	Nonlinear	Bi	Bi
SC∩DT	Bi	Bi	Nonlinear
PT∩HM	Nonlinear	Nonlinear	Nonlinear
PT∩PR	Nonlinear	Nonlinear	Nonlinear
PT∩ST	Bi	Nonlinear	No-linear
PT∩ET	Nonlinear	Nonlinear	Nonlinear
PT∩DT	Nonlinear	Nonlinear	Nonlinear
HM∩PR	Nonlinear	Nonlinear	Nonlinear
HM∩ST	Nonlinear	Nonlinear	Nonlinear
HM∩ET	Nonlinear	Nonlinear	Nonlinear
HM∩DT	Nonlinear	Nonlinear	Nonlinear
PR∩ST	Nonlinear	Nonlinear	Nonlinear
PR∩ET	Bi	Bi	Nonlinear
PR∩DT	Nonlinear	Bi	Nonlinear
ST∩ET	Nonlinear	Nonlinear	Nonlinear
ST∩DT	Nonlinear	Nonlinear	Bi
ET∩DT	Nonlinear	Bi	Nonlinear

Bi refers to bi-factor enhancement, and nonlinear refers to nonlinear enhancement.

In 2015, the interactions between the level of economic development (ED) [41] and the progression of the digital economy (PT), as well as the standard of technological innovation (ST) and other factors, affected the efficiency in the tourism sector, which produced a nonlinear enhancement effect, while the other factors interacted on the tourism ecological efficiency, which produced a two-factor enhancement effect, but the interaction was not significant. This shows that we should take note of the interaction between the standard of economic development, the progression of the digital economy, and the standard of technological innovation in the promotion of tourism ecological efficiency. According to Table 6, the explanatory powers of the interactions between the social consumption standard (SC) [42], degree of opening up (IE), energy-technology level (ET), government intervention level (PR), energy-technology level (ET), science-and-technology-innovation level (ST), and government intervention level (PR) [43] are in the top four of all the interactive factors. The reasons for this are the tourism ecological efficiencies and social consumption standards of the 21 cities in Guangdong Province in 2015. The degree of opening up and the levels of energy technology, government intervention, and scientific and technological innovation are inseparable. The comprehensive interaction between the above factors could significantly promote an improvement in the tourism ecological efficiencies of the 21 cities in Guangdong Province.

In 2021, the interactions between the progression of the digital economy (PT), the standard of transportation infrastructure (HM), the level of government intervention (PR), and other factors and the tourism ecological efficiencies had nonlinear enhancement effects [44], while the other factors had two-factor enhancement effects when interacting with the tourism ecological efficiency, but the interaction was not significant. This shows that we should pay attention to the interplay of the progression of the digital economy, the standard of transportation infrastructure, and the level of government intervention in the promotion of efficiency in the tourism sector. In Table 7, the explanatory powers of the interactions between the traffic driving force (DT) and social consumption level (SC), technological innovation (ST) and social consumption level (SC), technological innovation level (ST) and progression of the digital economy (PT), and traffic driving force (DT) and traffic infrastructure level (HM) are in the top four of all the interactive factors. The reason for this is that, in 2021, the combined interaction of these factors significantly contributed to an improvement in the efficiency in Guangdong Province, which was inextricably linked to factors such as transportation drivers, the social consumption level, the technological innovation level, the progression of the digital economy, and the transportation-infrastructure level.

Compared with 2009 and 2021, when assessing the effects of the interactions of other factors on the tourism ecological efficiency [45], an increasing number of factors produce nonlinear enhancement effects. In 2021, the progression of the digital economy (PT) and the standard of government intervention (PR) were added, indicating that we should pay attention to the interplay between the drivers of the progression of the digital economy (PT) and the level of government intervention (PR) in the increase in the efficiency. In 2009, the efficiency in the tourism sector in Guangdong Province was inseparable from the energy-technology level, transportation-infrastructure level, social consumption level, economic development level [46], government intervention level [47], transportation driving force, and other factors. The comprehensive interaction between these factors could significantly promote the increase in the tourism ecological efficiency in Guangdong Province. In 2021, the efficiency in the tourism sector in Guangdong Province was inseparable from such factors as the traffic driving force, social consumption level, technological innovation level, development of the digital economy, and transportation-infrastructure level. The comprehensive interaction of the above factors could significantly improve the tourism eco-efficiencies of the 21 cities in Guangdong Province. The addition of two driving factors, namely, the technological innovation level and the development of the digital economy, shows that Guangdong Province has begun to attach importance to technological innovation and the progression of the digital economy in recent years; however, it still needs to commit to the enhancement of factors such as the transportation driving force, the level of transportation facilities, and the social expenditure standard, which have reduced the standards of energy technology, economic development, and government intervention. The energy technology, economic development, and government intervention levels of the 21 cities in Guangdong Province have been improved. The urban power generation and economic development [48] are at the developed level for the country, and government intervention measures do not need to be significantly strengthened.

4. Conclusions and Suggestions

The sustainable development of ecotourism is conducive to the realization of the quality and efficiency of the regional economy, prompting the transformation of the structure of the tourism economy into an intensive structure [49]. The development of ecotourism can promote environmental protection [50], and it also enriches the ecotourism industry and promotes sustainable tourism [51]. Furthermore, Guangdong Province and the neighboring Hong Kong and Macao are also important transit places for cross-border tourism, as well as important hinterlands for the construction of strategic industries and the development of advanced technology in the Guangdong–Hong Kong–Macao Greater Bay area. In this study, we measured the tourism eco-efficiencies considering the environmental pollution factor, analyzed the spatial difference characteristics of the full tourism-efficiency range and, finally, calculated the interaction characteristics of the integrated drivers that affect the spatial evolution of the tourism efficiencies. Regarding the analysis of the tourism ecological efficiencies, Zhuhai city, Shenzhen city, Guangzhou city, Meizhou city, Zhanjiang city, Maoming city, Jieyang city, and Yunfu city are all in effective states.

Regarding the superefficiency of tourism, comparing 2009 and 2021, the tourism ecological efficiencies of Shanwei city and Chaozhou city had the most significant changes, decreasing by 2.533 and increasing by 0.893, respectively, while Zhaoqing city and Qingyuan city had the second most significant changes, decreasing by 0.672 and 0.592, respectively. The tourism ecological efficiencies of Shenzhen city, Huizhou city, Foshan city, Zhongshan city, Yangjiang city, Zhanjiang city, Maoming city, Yunfu city, Jieyang city, and Chaozhou city show increasing trends, the tourism ecological efficiencies of Guangzhou city, Heyuan city, Zhuhai city, Shaoguan city, Shantou city, Meizhou city, Shanwei city, Dongguan city, Jiangmen city, Zhaoqing city, and Qingyuan city show decreasing trends, while the tourism ecological efficiencies of Zhuhai city, Guangzhou city, Meizhou city, Shanwei city, Zhaoqing city and Qingyuan city are still in an effective state after decreasing.

The mean value of the tourism ecological efficiencies of the 21 cities in Guangdong Province from 2009 to 2021 is 1.407, and it has a fluctuating downward trend. The difference between the mean tourism ecological efficiencies of the two echelons of cities, one of which is located above the mean and one located below the mean, is large. Overall, the tourism ecological efficiency in Guangdong Province is in a high-ranking position, and the ecological efficiency in the tourism sector is basically above 1 in all years, reflecting that there is some room for improving the ecological efficiency in the tourism sector in Guangdong Province.

With regards to the final consequence of the space–time discrepancy in the ecological efficiency in the tourism sector, compared with 2009 and 2021, Guangzhou city changed from an area with a relatively high level of tourism ecological efficiency to an area with a high level of tourism ecological efficiency. Shenzhen city changed from an area with a relatively low level of tourism ecological efficiency to an area with a relatively high level of tourism ecological efficiency. Zhuhai city changed from an area with a medium tourism level of ecological efficiency to an area with a relatively high level of tourism ecological efficiency. Shantou city remains a low-tourism-ecological-efficiency area. Foshan city changed from an area with a low level of tourism ecological efficiency to an area with a relatively low level of tourism ecological efficiency. Shaoguan city is still a region with relatively low tourism ecological efficiency. Heyuan city transformed from a region with medium tourism ecological efficiency into a region with a relatively low level of tourism ecological efficiency. Meizhou city is still a region with medium tourism ecological efficiency. Huizhou city transformed from a region with a low level of tourism ecological efficiency into a region with medium tourism ecological efficiency. Shanwei city transformed from a region with a high level of tourism ecological efficiency into a region with a relatively high level of tourism ecological efficiency. Dongguan city changed from a region with medium tourism ecological efficiency to a region with a relatively low level of tourism ecological efficiency. Zhongshan city changed from a region with low tourism ecological efficiency to a region with a relatively low level of tourism ecological efficiency. Jiangmen city changed from a region with a low level of tourism ecological efficiency to a region with a relatively low level of tourism ecological efficiency. Yangjiang city changed from a region with a relatively low level of tourism ecological efficiency to a region with a relatively high level of tourism ecological efficiency. Zhanjiang city changed from an area with medium tourism ecological efficiency to an area with a high level of tourism ecological efficiency. Maoming city changed from an area with medium tourism ecological efficiency to an area with a high level of tourism ecological efficiency. Zhaoqing city changed from an area with a relatively high level of tourism ecological efficiency to an area with medium tourism ecological efficiency. Qingyuan city changed from an area with a relatively high level of tourism ecological efficiency to an area with medium tourism ecological efficiency. Chaozhou city changed from a region with a relatively low level of tourism ecological efficiency to a region with a high level of tourism ecological efficiency. Jieyang city changed from a region with relatively low tourism ecological efficiency to a region with a medium level of tourism ecological efficiency. Finally, Yunfu city changed from a region with a relatively low level of tourism ecological efficiency to a region with a relatively high level of tourism ecological efficiency.

In terms of the spatial-trend surface analysis of the ecological efficiencies in the tourism sector, compared with 2009 and 2021, the tourism ecological efficiencies in Guangdong Province generally changed from a trend of high in the north and low in the south and low in the west and high in the east to a trend of low in the north and high in the south and high in the west and low in the east. In addition, there is a U-shaped distribution in both the north–south and east–west directions, and the spatial difference between the north–south and east–west directions is more obvious.

In the analysis of the influences on the spatiotemporal divergence of the ecological efficiencies in the tourism sector, compared with 2009 and 2021, the four factors with the strongest explanatory powers changed from the level of government intervention, the standard of transportation infrastructure, the level of energy technology, and the extent of opening up to the level of technological innovation, the level of the transportation driving force, the level of opening up to the outside world, and the level of economic development. The four factors with the weakest explanatory powers changed from the progression of the digital economy, economic development, technological innovation, and social consumption to the level of government intervention, social consumption, the progression of the digital economy, and transportation infrastructure.

The interaction between these factors has a significant impact on the ecological efficiencies in the tourism sector in Guangdong Province and is preferable to an analysis of the effect of a single factor on the spatial distribution of the tourism ecological efficiencies. Compared with 2009 and 2021, when assessing the effects of the interactions of other factors with the tourism ecological efficiencies, an increasing number of factors produce a nonlinear enhancement effect. In 2021, the progression of the digital economy (PT) and the standard of government intervention (PR) were added, indicating that we should pay attention to the interplay between the drivers of the progression of the digital economy (PT) and the standard of government intervention (PR) in the increase in ecological efficiency in the tourism sector. In 2021, the levels of technological innovation and the progression of the digital economy were added as two driving factors, indicating that Guangdong Province has begun to attach importance to the level of scientific and technological innovation and the development of the digital economy in recent years, while still paying attention to the strengthening of the transportation driving force, the level of transportation infrastructure, the standard of social consumption, and other factors, as well as to reducing the standards of energy technology, economic development, and the level of government intervention. This shows that the energy technology, economic development, and government intervention levels in Guangdong Province have improved over the past 13 years. The urban power generation and economic development are at the developed level for the country, and government intervention measures do not need to be significantly strengthened.

To increase the ecological efficiency in the tourism sector in Guangdong Province, we make the following recommendations. To realize the true sustainability of the digital culture and tourism sector, the online development of traditional arts, such as Cantonese opera, should be realized, as well as the promotion of the online and offline integration of traditional cultures, such as literature and the arts [52]. Cultural expositions and non-heritage attractions [53], performing-arts tourism projects, online performance projects, digital experience projects, and digital art experiences should be cultivated, and the gathering of digital culture and travel equipment for research and development should be strengthened. Through digital transformation, the cultural tourism industry can better adapt to market demand, improve the tourism experience, promote the development of the cultural industry, and achieve sustainable development. The development of smart tourism and high-tech tourism products and the construction of scenic smart-tourism spots should be accelerated. Moreover, a monitoring platform for A-class scenic spots should be developed, and the normalization of limited, reserved, and staggered tours should be promoted, strengthening sustainable channels for cultural dissemination and broadening communication pathways.

On 19 August 2023, the Ministry of Culture and Tourism of China issued a milestone document titled "Notice on Sustainable Development of Culture and Tourism Industry Driven by Technology", proposing to strengthen the guidance of technological innovation for cultural and tourism enterprises, promote the widespread application of digital technology in the field of cultural and tourism, and improve the experience of and service level for tourists. The level of technology and the establishment of smart libraries, smart museums, digital cultural museums, digital art galleries, and cloud theatres in Guangdong Province should be enhanced to improve visitor participation, and the quality of the public tourism technology and cultural services should be improved. Innovation in tourism models, tourism formats, and tourism products, new cutting-edge-technology business models, digital creativity, cultural creativity [54], and integrated services should be improved. The government should actively play an important enabling role in technological innovation in tourism development by, for example, adopting technological means to promote Lingnan culture, protecting intangible cultural heritage, innovating in new media communication channels for culture, and strengthening the exploration of new approaches, such as audio libraries and interactive experiences in cultural centers. Popular education and exhibitions, experiences, and teaching practices on non-traditional culture should be carried out. Technology services based on new technology applications, such as 5G, and the organization of non-heritage shopping festival activities in Guangdong Province on Internet platforms should be utilized. The display and creative design of non-heritage cultural products should be broadened. In addition, tourist meta-universe technology pavilions should be created, technology-experience equipment should be improved, tourist technology-demonstration parks should be set up, and key laboratories for culture and tourism, as well as demonstration zones for the integration and development of cultural and tourism industries, should be declared. The government [55] should insist on innovation-driven cultural industry development and promote the optimization and upgrading of the cultural industry's innovation chain, transform and upgrade traditional cultural industries, and strengthen the application of technology in traditional cultural industries, such as the performing arts, entertainment, arts and crafts, and cultural exhibitions, promote the sustainable continuation of the cultural industry chain, innovate in tourism methods and experiences, and provide tourists with sustainable cultural and tourist products with local characteristics.

Moreover, the tourism-transportation infrastructure [56] and land-, sea-, and air-transportation modes should be improved to facilitate movement to and from travelers' destinations [57] and places of origin, thereby increasing passenger turnover. Tourism distribution, service, and consultation centers should be further optimized, improved tourism-consultation centers, tourism roads, tourism signs, and other tourism-transport infrastructure in A-class scenic spots should be constructed, as well as book-reading bars and APP platforms for positioning tourist attractions in relation to toilet services, and the upgrading of tourist public service facilities should be promoted. The differentiation of transport roads for the disabled, the elderly, and minors needs to be considered. The construction of self-driving and car-touring camps and self-driving tourism routes, such as the South Guangdong Ancient Post Road tourism route and five high-quality rural tourism routes, Tangjiawan in Zhuhai, the Nan'ao Roundabout in Shantou, the Qiao Ancient Road in Zhongshan, Gaozhou in Maoming, and the Meixian District in Meizhou, should be improved. The quality of the services provided by the tourism industry can be improved, as well as the level of sustainable management, planning facilities for local tourism [58], and the sustainability of tourist hospitality and services, which will help to achieve the sustainable development of the tourism sector.

In addition, the building of national cultural and tourist consumption demonstration cities, tourism-consumption-center cities, and nighttime cultural and tourism-consumption clusters should be promoted. Each prefecture-level city could organize cultural consumption seasons (months and weeks) and other multiform consumption-promotion activities according to the local conditions, improve consumption subsidies, points rewards, scenic spot ticket reductions, and other consumer benefit measures, and create cultural and tourism-consumption-city clusters, hot-spot shopping areas, and community-benefit circles. The quality of tourism products should be enhanced to promote consumption. Care should be taken during the construction of the Hong Kong–Zhuhai–Macao Bridge, Guangzhou Tower, and Zhuhai Hengqin International Leisure and Tourism Island, and the marketing and promotion of theme parks [59], such as Changlong and Rongchuang, should continue, in order to improve the quality of tourism services and establish quality tourism resorts with cultural heritage [60]. According to the "Work Plan for Guangdong Province to Carry out the 2023" Hundred Cities and Hundred Districts "Financial Support for Cultural and Tourism Consumption Action", including six national cultural and tourism-consumption pilot cities (Guangzhou, Shenzhen, Foshan, Huizhou, Dongguan, and Jiangmen), as well as 11 national nighttime cultural and tourism consumption clusters, such as Beijing Road and Zhengjia Guangchang in Guangzhou, we will distribute cultural and tourism-consumption subsidy vouchers to the public, as well as utilizing measures, such as refunding the handling fees generated from the UnionPay transactions of small and microenterprises in a certain proportion, to promote tourism consumption. The optimization of the social consumption composition in the tourism sector will help to enhance the economic benefits and achieve the sustainable growth of the tourism economy [61].

Finally, the study of the relationship between the inputs and outputs of tourism resources is of considerable significance in order to accurately discuss the relationship between the resources invested in tourism and the outputs obtained. Moreover, it is of considerable significance for enriching the theory of ecotourism and sustainable tourism development, as well as for realizing efficient tourism development and protecting natural resources. Ecological protection and environment awareness should be promoted, and environmental protection signs at tourist attractions should be set up. Enhancing eco-efficiency in tourism can contribute to sustainability through cost reduction and efficiency gains. It is possible to monitor some local environmental pollution phenomena and evaluate the degree of achievement of regional tourism sustainability goals. The government should formulate regulations on rewards and punishments for environmental protection, thereby increasing the proportion of investment in environmental protection and further protecting the cultural ecology of the countryside. The consolidation of tourism and forestry, agriculture, and coastal leisure fishing fields in northern Guangdong, as well as the construction of ecological and leisure tourism heights, such as the Chunmuyuan–Lingnan Ecological Tourism Resort in Heyuan city, should be promoted. In terms of the growth of natural tourism resources, protecting the ecological environment [62] and ceasing the over-exploitation of natural resources should be considered. Tourism resources [63] should be reasonably allocated, the tourism economy should be transformed from one of high consumption to one of circular and economic growth, and the exhaust from tourism contamination should be minimized, thereby raising the utilization efficiency of ecological resources, ensuring the sustainability of ecotourism [64] and achieving the sustainable development goals of the environmental and tourism resources. The construction of high-quality tourism routes for ecological parks and ecotourism scenic spots in the Pearl River Delta region and the western Guangdong region should be strengthened, as well as the promotion of self-driving and ecological tourism, mountain tourism, etc., and the organization of relevant festival activities to provide tourists with deeper experiences of rural tourism. Future researchers can refer to this article and should aim to achieve the sustainable development of the tourism sector, environment, and resources.

In terms of shortcomings and improvements, this study still needs to be improved upon, and it is hoped that future researchers will add a variety of non-desired outputs, such as, for example, soot and sulfur dioxide emissions. The SBM model is measured from a static point of view and, if possible, it would be more complete to add a dynamic point of view to the model in future studies. Future investigations can investigate the data on some of the smoke, dust, and wastewater enterprises in the region to further illustrate the implementation effects of local policy measures.

Author Contributions: Introduction, data sources, research methods, results and analysis, and conclusions and suggestions, G.D. and H.H.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The sources of relevant data are described in the text.

Conflicts of Interest: The authors declare no conflicts of interest.

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