

Spatio-Temporal Evolution and Influencing Factors of Tourism Eco-Efficiency in China

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Abstract: Against the backdrop of the continuous expansion of the tourism industry and the in-depth advancement of ecological civilization construction, improving tourism eco-efficiency has become a pivotal pathway to achieving the goals of high-quality development of the tourism industry and the construction of Beautiful China. Taking 30 provincial-level regions in China (excluding Xizang Autonomous Region, Hong Kong, Macao and Taiwan) from 2011 to 2023 as the research sample, this paper measures tourism eco-efficiency by applying the Super-SBM model with undesirable outputs, and identifies its key influencing factors by adopting the panel Tobit model. The findings reveal that scientific and technological level, human capital and environmental regulation exert a significant positive impact on tourism eco-efficiency, while economic development level has a notable negative effect, which reflects that an extensive tourism growth model at the expense of resources and the environment still exists in some regions at present.

Keywords: Tourism eco-efficiency; Super-SBM model with undesirable outputs; Panel Tobit model; Ecological civilization construction; High-quality tourism development

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1. Introduction

As a pillar industry with a strategic supporting role in the national economic system, tourism has assumed an increasingly prominent position in the development paradigm of the new era^[1]. As a typical ecology-dependent industry, tourism not only inherently boasts resource endowment advantages for developing a “Beautiful Industry”, but also exerts an irreplaceable and unique role in advancing the construction of ecological civilization^[2]. The report to the 20th National Congress of the Communist Party of China has explicitly proposed the strategic arrangement of advancing the construction of Beautiful China, emphasizing the need to “adhere to the integrated protection and systematic governance of mountains, rivers, forests, farmlands, lakes, grasslands and deserts, and promote the synergetic development of industrial restructuring, pollution control and ecological protection in a coordinated manner”^[3]. This important exposition has not only set the value orientation for the high-quality

development of the tourism industry, but also put forward higher-dimensional practical requirements for the industry to strike a balance between ecological protection and industrial development. Nevertheless, with the rapid expansion of the tourism industry scale, the energy consumption and environmental pressure brought by tourism have become increasingly prominent, and the contradiction between tourism development and ecological protection urgently needs to be addressed. Therefore, an in-depth exploration of the temporal and spatial evolution of tourism eco-efficiency is conducive to breaking the resource and environmental constraints faced by the sustainable development of the tourism industry, thereby realizing the high-quality development of tourism.

The concept of eco-efficiency was first put forward by scholars such as Schaltegger in 1990^[4]. With the vigorous development of the tourism industry, ecological and environmental problems have gradually become a prominent and key restrictive factor for the development of tourism, against which the concept of tourism eco-efficiency emerged as the times require. It is defined as the ratio of the value of tourism products to the environmental costs incurred by the tourism industry^[5]. Foreign research on this topic started early, and the relevant studies mainly focus on four aspects as follows:

- (1) Drawing on the core concept of “minimum input and maximum output”, scholars have defined tourism eco-efficiency as the comprehensive performance of tourism regional systems in realizing the synergetic optimization of economic and environmental benefits while adapting to and protecting the natural ecology through intensive, low-carbon and sustainable tourism development models^[4,6-9];
- (2) Researchers have constructed evaluation indicators from both input and output dimensions, and adopted various methods to measure tourism eco-efficiency, including the single ratio method, three-stage DEA model, Super-SBM model with undesirable outputs, and DEA game cross-efficiency model with undesirable outputs^[6,8,10,11];
- (3) The research objects cover the Yellow River Basin, the Yangtze River Basin, the Dongting Lake Area, as well as provincial-level administrative regions (provinces, autonomous regions and municipalities directly under the Central Government) in China^[8,12,13];
- (4) Existing studies have explored the influencing factors of tourism eco-efficiency, focusing on key variables such as the scale of tourism economy, investment in technological innovation, industrial structure, urbanization level, intensity of environmental regulation, transportation infrastructure, government regulation, tourism resource endowment and digital economy^[9,10].

To date, fruitful research outcomes have been achieved in the field of tourism eco-efficiency; however, few studies have directly explored the influencing factors of China’s tourism eco-efficiency at the national scale. In view of this, this paper takes 30 provincial-level administrative regions in China (excluding the Xizang Autonomous Region, Hong Kong, Macao and Taiwan) as the empirical research sample, systematically reviews the existing research findings on tourism eco-efficiency, and comprehensively employs the Super-SBM model with undesirable outputs and the panel Tobit model to analyze the temporal and spatial evolution patterns of China’s tourism eco-efficiency. This study aims to provide useful references for the realization of sustainable development and high-quality development of China’s tourism industry.

2. Research methodology and data sources

2.1. Evaluation index system of tourism eco-efficiency

Drawing on existing research findings, this study systematically constructs an evaluation index system of tourism eco-efficiency based on the input-output theoretical framework^[8,13]. From the two dimensions of resource factor

input and output benefits, the system comprehensively examines the resource consumption, environmental impact and comprehensive benefits generated in the development of the tourism industry, thus providing a quantitative analysis basis for the scientific evaluation of tourism eco-efficiency. The index system consists of 2 first-level indicators, 5 second-level indicators and 10 third-level indicators (**Table 1**).

Table 1. Indicator system of tourism eco-efficiency

First-level indicator	Second-level indicator	Third-level indicator
Input	Labor force	Number of tourism employees (persons)
	Resources	A-level Scenic Area Score = $5 \times 5A + 2.5 \times 4A + 0.75 \times 3A + 0.5 \times 2A + 0.25 \times 1A$ Number of tourism accommodation enterprises (units) Number of travel agencies (units)
Output	Capital	Tourism fixed asset investment (100 million yuan)
	Desirable output	Total tourism revenue (100 million yuan)
		Total tourist visits (100 million person-times)
	Undesirable output	Tourism carbon emissions (10,000 tons)
		Tourism SO ₂ emissions (tons)
Tourism wastewater discharge (10,000 tons) Tourism smoke and dust emissions (tons)		

2.2. Super-SBM model with undesirable outputs

The Super-SBM model with undesirable outputs captures the dynamics of the production process and the temporal variation trend of efficiency by analyzing panel data. Its non-radial, super-efficiency and dynamic characteristics are highly consistent with the multidimensional, temporal and improvable attributes of tourism eco-efficiency. For this reason, this model is adopted to measure tourism eco-efficiency in this study.

2.3. Panel Tobit model

To further explore the impacts of various influencing factors on tourism eco-efficiency in the Dongting Lake Area, this study takes into account that tourism eco-efficiency is a set of left-censored data with values greater than zero. As the Tobit model is a regression model applicable for the dependent variable that takes values under certain continuous constraints, this paper thus adopts the Tobit model to analyze the nature of the impacts of external variables on tourism eco-efficiency^[13].

2.4. Data sources

The research sample comprises the panel data of new productive forces and tourism eco-efficiency across 30 provincial-level regions in China from 2011 to 2023, excluding the Xizang Autonomous Region, Hong Kong, Macao and Taiwan due to data unavailability. The data are mainly sourced from the 2012–2024 editions of the China Statistical Yearbook, China Tourism Statistical Yearbook, China Environmental Statistical Yearbook, China Culture, Relics and Tourism Statistical Yearbook, China Energy Statistical Yearbook, as well as the CSMAR Database, China Emission Accounts and Datasets (CEADs) and other relevant databases. For individual missing data entries, the interpolation method is applied for conversion and supplementation.

3. Research on the influencing factors of tourism eco-efficiency

This paper employs the Tobit model to explore the main factors influencing tourism eco-efficiency and their underlying impact mechanisms. Tourism eco-efficiency is primarily affected by economic development, technological innovation, human capital, environmental regulation and other factors. Specifically, per capita GDP is selected as the specific indicator for economic development, R&D expenditure for scientific and technological level, urbanization level for human capital, and the proportion of fiscal expenditure on environmental protection in local government fiscal expenditure for environmental regulation.

The results of the Tobit model analysis (**Table 2**) reveal that scientific and technological level, human capital and environmental regulation exert a significant positive impact on tourism eco-efficiency, whereas economic development has a significant negative impact on it. Economic development exerts a significant negative impact on tourism eco-efficiency. The possible reasons are that rapid economic growth is often accompanied by the drastic expansion of tourism scale, which leads to intensified resource consumption, increased energy usage and rising waste emissions, thus directly exacerbating ecological and environmental pressures. On the other hand, the economic development of some regions may over-rely on an extensive tourism development model, neglecting ecological protection in infrastructure construction and the management of tourism activities. In addition, scientific and technological level has a significant positive impact on tourism eco-efficiency. This is because technological progress can bring innovative development models to the tourism industry, such as smart tourism which enhances service efficiency and tourist experience. Meanwhile, the application of technologies in ecological and environmental monitoring and protection can improve ecological and environmental sustainability, thereby facilitating the coupled and coordinated development of the tourism industry and the ecological environment.

Human capital exerts a significant positive impact on tourism eco-efficiency. This may be due to the continuous improvement of infrastructure and the enhancement of transportation, accommodation and other supporting conditions in the process of urbanization, which attracts more tourists and boosts the development of the tourism industry. At the same time, urbanization also raises the attention paid to ecological and environmental governance and protection. Nevertheless, excessive urban development in some regions may impose ecological pressures, yet the positive effect remains more prominent on the whole. Environmental regulation has a significant positive impact on tourism eco-efficiency. The possible reasons are that stringent environmental protection policies can force tourism enterprises to optimize their production models. For example, emission standard restrictions can drive hotels to upgrade their sewage treatment facilities, and ecological compensation mechanisms can prompt scenic spots to reduce development intensity. In the meantime, environmental regulation can guide tourism investment to tilt toward green technology fields, such as promoting the utilization of renewable energy and the adoption of low-carbon transportation modes.

Table 2. Regression results of external influencing factors on tourism eco-efficiency

Variable	Basis for indicator selection	Coefficient	P-value
Economic development	Per Capita GDP	-0.418***	0.000
Scientific and technological level	R&D expenditure	0.150**	0.041
Human capital	Urbanization rate	0.218**	0.032
Environmental regulation	Proportion of environmental protection investment in GDP	0.297***	0.000

Note: The dependent variable is the tourism eco-efficiency value; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4. Conclusion

Based on panel data from 30 provincial-level regions in China during 2011–2023, this study measures tourism eco-efficiency using the Super-SBM model with undesirable outputs and empirically examines its influencing factors through a panel Tobit model. The results show that China's tourism eco-efficiency is significantly promoted by technological progress, human capital, and environmental regulation, while economic development exerts a notable negative effect, indicating that an extensive growth pattern remains prevalent in some regions. These findings suggest that improving tourism eco-efficiency requires shifting toward innovation-driven, talent-supported, and regulation-guided development paths, so as to achieve the coordinated advancement of ecological protection and high-quality tourism development under the framework of ecological civilization construction.

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