Carbon Emissions of China Tourist Hotels Based on Supply Chain

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Abstract. As one of the important sectors of tourism, the accommodation industry's carbon emission has become a hot research topic in emission reduction. This research constructs a research framework from the perspective of the supply chain and analyzes the carbon emissions of China's tourist hotels including the supply chain from 2002 to 2019. The research results show that: (1) The direct carbon emissions of Chinese tourist hotels are on the rise, while the indirect carbon emissions are on the decline. (2) The carbon emissions of most provinces in the west of the Huhuanyong Line are on the rise, while the carbon emissions of most provinces in the east show an inverted U-shaped curve that rises first and then falls, which conforms to the environmental Kuznets curve. (3) There is the Engel coefficient effect in tourist hotels, and food manufacturing and tobacco processing industry are the main sources of indirect carbon emissions. (4) The indirect carbon emissions of the hotel are developing well, and it is expected to take the lead in decoupling hotels through indirect carbon emissions. This paper aims to provide scientific and technological tools and support for the precise management and regulation of the carbon peak of tourist hotels and provide a reference for the development of the hotel in China and similar countries with new economies.

Keywords: tourist hotels, carbon emissions, supply chain, input-output analysis, China.

1 Introduction

As the core sector of tourism, the accommodation industry is regarded by many countries and regions as an advantageous industry, a window industry, and a leading industry for implementing low-carbon economic transformation [1]. From 2016 to 2019, the global hotel market scale exceeded US $ 1 trillion for four consecutive years and showed a growing trend [2]. However, the close relationship between the hotel and other industries, there are a large number of intermediate input links in its supply chain [3], which leads to a significant amount of carbon emissions from hotels, including direct and indirect carbon emissions. Especially indirect carbon emissions, which are often overlooked by researchers, its impact cannot be underestimated. Researchers found that the global tourism carbon emissions, including the supply chain, are four

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times the direct carbon emissions [4]. Therefore, the precise control of indirect carbon emissions of tourist hotels through the supply chain is an accurate management tool for the future carbon peak of tourist hotels, and an effective control tool for the rapid recovery of the global tourism economy and the realization of low-carbon tourism development in the post-epidemic era. The research results are conducive to finding the best path for the green, high-quality, and sustainable development of tourist hotels.

As the largest carbon emitter in the world, China's carbon emission reduction policy has attracted global attention [5]. And China's accommodation industry is very special and representative [6]. After China adjusted the epidemic prevention and control measures and resumed work and production in an orderly manner, China's tourism industry showed a rapid recovery. During the Spring Festival in 2023, China's domestic tourism income has recovered to 88% of the same period in 2019. The carbon emissions of the accommodation industry are at risk of becoming the accelerator of China's tourism carbon emissions.

The research on the carbon emissions of the accommodation industry has become the focus of more and more countries and scholars, such as Spain [7], Mexico [8], and Italy [9], etc. The research on carbon emissions from the hotel mainly focuses on three aspects. First, the measurement of carbon emissions from energy use in the accommodation industry [10]. The second is the study on the factors affecting the carbon emissions of the accommodation industry [11]. Third, research on energy conservation and emission reduction measures of hotels [12]. To sum up, many efforts have been made and good research results have been achieved in the field of carbon emissions in the hotel. However, the measurement of carbon emissions in the supply chain of tourist hotels is still insufficient. The relationship between carbon emissions and income in the hotel needs to be further studied.

This paper tries to fill the knowledge gap from the following aspects: First, what are the spatial distribution and evolution characteristics of direct and indirect carbon emissions? Second, which sectors are the indirect sources of carbon emissions of tourist hotels? Third, what is the coupling relationship between the income and the carbon emissions? Fourthly, how does the carbon emission efficiency of tourist hotels change under different carbon emission scenarios?

2 Method

Calculation of carbon emissions

Calculation of carbon emissions: The calculation of direct carbon emissions of tourist hotels is mainly based on the standards formulated by the United Nations Intergovernmental Panel on Climate Change (IPCC), the energy emission coefficient of the corresponding industry corresponding to the income of each department, and the carbon emission coefficient. The specific steps are as follows:

Firstly, the total energy consumption multiplied by energy consumption of the accommodation and catering industry divided by the added value of the accommodation and catering industry yields the energy emission coefficient of China's

tourist hotels. And the energy emission coefficient of China's tourist hotels is multiplied by the income of the tourist hotel to obtain the direct carbon emission.
Total Carbon Emissions: The proportion of the income of tourist hotels in the final use of the accommodation and catering industry sector is used to calculate the intermediate use and intermediate input of tourist hotels to other sectors.

$$z^{i\sim th} = \frac{TR^{th}}{f^{ac}} z^{i\sim ac} \quad (1)$$

Among them, f^{ac} represents the final use of the accommodation and catering industry, TR^{th} represents the income of tourist hotels, and $z^{i\sim ac}$represents the intermediate use of the accommodation and catering industry to other industry sectors *i*.
Then, calculating the relationship between the total economic output and the total final use. The complete carbon emission formula of the tourist hotels including indirect carbon emissions is expressed as follows:

$$CET^{th}_{\text{total}} = \mu \times \eta^{th} \times X^{th}_{t} \quad (2)$$

Indirect Carbon Emissions: This paper uses the input-output data of the accommodation and catering industry to reflect the energy consumption of the hotel. Each department can calculate the indirect carbon emission of tourist hotels according to the investment proportion.

Coupling analysis of carbon emissions and tourism income

Coupling analysis comes from physics [13]. This paper expects to further point out the direction for coordinating the economic and ecological relationship of tourist hotels based on the evaluation of the current situation of the economic and ecological development of tourist hotels in China through the coupling analysis between the operating income and carbon emissions of tourist hotels. Couple the operating income (I) of China's tourist hotels in 2002 and 2019 with direct carbon emissions (DC) and indirect carbon emissions (IC) respectively, and use the same relative effective as the dividing line to divide China's tourist hotels into four types.

Assessment of the Carbon Emission Efficiency of Tourist Hotels of China: Super-SBM model

This study measures the efficiency of direct carbon emissions and total carbon emissions (including direct and indirect carbon emissions) of tourist hotels, including the supply chain, by constructing a Super-SBM (Slack Based Measure model) that includes unexpected output. The Super-SBM model includes input indicators, expected output indicators, and non-expected output indicators.

Indicators

This paper uses the number of hotel employees and fixed assets investment as input indicators, hotel industry income as output indicators, and direct carbon emissions and

complete carbon emissions as unexpected outputs to measure the carbon efficiency of China's tourist hotels under different carbon emission scenarios. As shown in Table 1.

Table 1. Input-output indicators for evaluating carbon emission efficiency of China's tourist hotels

Indicators		Unit
Input	Labor	10k people
	Investment	Million
Output	Income	Million
Undesirable output	Direct carbon emissions/Total carbon emissions	Ton

3 Result

Carbon emission trend of tourist hotels in China

The direct carbon emissions of China's tourist hotels show an increasing trend, while the indirect carbon emissions show a downward trend. The indirect carbon emissions of China's tourist hotels showed a downward trend from 2002 to 2019, which was significantly different from the linear upward trend of five-star hotels. This shows that the higher the level of comprehensive supporting services, the lower the indirect carbon emissions of China's star hotels, and the overall performance of China's tourist hotels is that the indirect carbon emissions are less than the direct carbon emissions, which is slightly inconsistent with the carbon emission law of the tourism industry [14]. This shows that tourist hotels can reduce indirect carbon emissions of the hotel by improving the level and quality of comprehensive supporting services, and then taking the lead in achieving the decoupling of the hotel and promoting the peak carbon neutralization of the tourism industry.

Characteristics of the spatial distribution of Direct Carbon Emissions and Indirect carbon emissions

From the perspective of spatial distribution, the overall carbon emissions of China's tourist hotels are high in the east and low in the west, high in the south and low in the north. As shown in (see Fig. 1_a), the direct carbon emissions of China's tourist hotels increased as a whole in 2019. According to the (see Fig. 1_b), it can be seen that the direct carbon emissions of tourist hotels in the southeast coastal area increased to the peak over time and then decreased, and this downward trend has the trend of transferring to the inland of China. From the perspective of the spatial distribution of indirect carbon emissions, the overall carbon emissions of China's tourist hotels have a significant downward trend, and the carbon emissions in the eastern region are falling faster than those in the western region. From the perspective of carbon emission trends in various provinces, most of China's tourist hotel carbon emissions are in a fluctuating

downward trend, with the largest decline in Beijing, Shanghai, and Guangdong, due to advanced development concepts and green awareness.

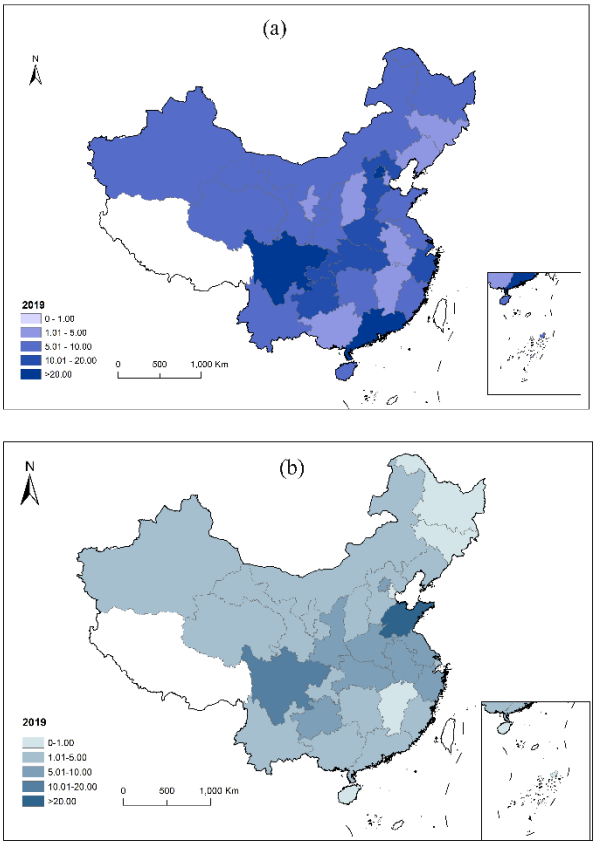

Fig. 1. Spatial distribution pattern and change trend of direct(a) and indirect (b) carbon emissions of China's tourist hotels in 2019

Indirect carbon emission source analysis

China's tourist hotels have Engel's law effect, and the food manufacturing and tobacco processing industry are the main sources of indirect carbon emissions. The sectors that contribute the most to the indirect carbon emissions of China's tourist hotels are the food manufacturing and tobacco processing industry, which contributed 37.93% to the indirect carbon emissions of tourist hotels in 2002, 47.58% in 2007, 51.54% in 2015 and 47.91% in 2017. It shows that the hotel also has the "Engel's Law" effect, and the food manufacturing and tobacco processing industry has an inverted U-shaped curve in the proportion of carbon emissions of tourist hotels.

The contribution of agriculture, forestry, animal husbandry, and fishery has declined year by year, from 24.00% in 2002 to 15.36% in 2017. It is noteworthy that the transportation industry is becoming a major contributor to indirect carbon emissions,

and the government and relevant departments should pay attention to and control it on time.

Coupling analysis of income and carbon emission

The slope of the regression line of China's tourist hotels has decreased year by year and is gradually decoupling. As shown in (see Fig. 2). In the next few years, hotel enterprises should mainly control the direct carbon emissions of tourist hotels. Most provinces and regions in China are realizing a steady transition from type III regions to type II regions, that is, from low-income and low-carbon emissions to high-income and high-carbon emissions, and this trend will continue in the coming years.

China's tourist hotel indirect carbon emissions are developing well and are expected to take the lead in decoupling. From 2002 to 2019, the slope of the regression line decreased from 0.10 to 0.05, and the changing intensity of the slope was greater than that of the direct carbon emissions. This indicates that China's tourist hotels are expected to realize the overall decoupling of the tourism industry through the early decoupling of indirect carbon emissions.

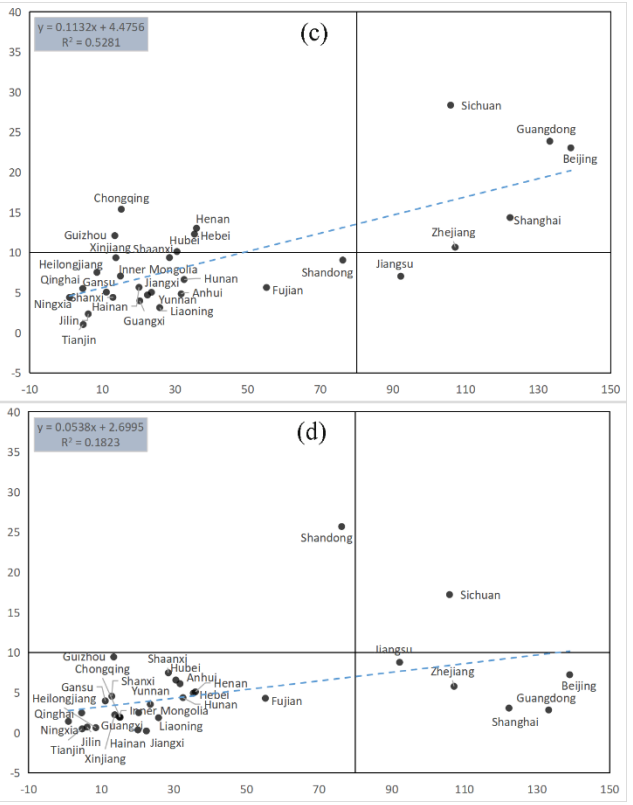

Fig. 2. Coupling relationship between income and carbon emissions (c. Direct carbon emissions and income coupling in 2019, d. Indirect carbon emissions and income coupling in 2019)

Carbon emission efficiency of tourist hotels in China

The carbon emission efficiency of China's tourist hotels under the direct carbon emission scenario is generally higher than that under the complete carbon emission scenario, showing a W-shaped curve. As shown in (see Fig. 3), the carbon emission efficiency under the direct carbon emission and complete carbon emission scenarios fluctuated between 0.75-0.85 and 0.65-0.85, respectively.

The carbon emissions peaked in 2005 and 2006, and the resource level, traffic conditions, and urbanization water were at a low development stage on average, which could not make up for the extremely high carbon emissions, resulting in a low carbon emission efficiency in 2006. The peak of carbon emission efficiency occurred in 2008 and 2012, indicating that the idea of holding the 2008 Beijing Green Olympics directly reduced the carbon emissions of the hotel.

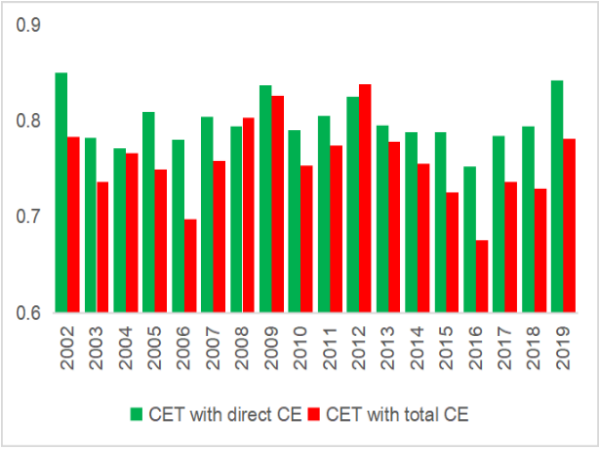

Fig. 3. The efficiency of direct and total carbon emissions of China's tourist hotels

4 Discussion

Previous studies have shown that the carbon emissions of China's tourism industry are increasing, and the indirect carbon emissions are significantly greater than the direct carbon emissions [15], but in this paper, the law of tourist hotel is different from that of the tourism industry. This study shows that the indirect carbon emissions of tourist hotels have decreased rapidly and are less than the direct carbon emissions, which indicates that China's tourist hotels are expected to take the lead in decoupling the hotel by continuously improving their supply chain, thus achieving the goal of optimizing and controlling the carbon emissions of the tourism industry.

The indirect carbon emission sources of China's tourist hotels are food manufacturing and tobacco processing industry, and the contribution rate to indirect carbon emission presents an inverted U-shaped curve, which is consistent with the results of the study on the sources of greenhouse gases in British hotels by [16], confirming the relevant research of [17] on the increase of customers' food consumption.

5 Conclusions

The direct carbon emissions of China's tourist hotels show an increasing trend, while the indirect carbon emissions show a downward trend. From the perspective of spatial distribution, the spatial and temporal distribution of carbon emissions from China's tourist hotels is extremely unbalanced, which is the result of the joint action of socio-economic and natural factors. Specifically, the carbon emissions of most provinces in the west of the Huh uanyong Line are on the rise, while the carbon emissions of most provinces in the east show an inverted U-shaped curve of first growth and then decline, in line with the environmental Kuznets curve. The food processing and tobacco manufacturing industry are the main contributors to the indirect carbon emissions of China's tourist hotels, and the hotel also has the "income Engel's law".
The slope of the regression line of China's tourist hotels has decreased year by year and is gradually decoupling. The carbon emission efficiency of China's tourist hotels under the direct carbon emission scenario is generally higher than that under the complete carbon emission scenario, showing a W-shaped curve.

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