

Decoupling and decomposition analysis on the CO₂ emissions of tourism industry: A case study of Hainan

Yong Yang^{1,2}, Junsong Jia^{1,*}, Chunyan Liu¹ and Duanqian Mao¹

¹School of Geography and environment / (Key Laboratory of Poyang Lake Wetland and Watershed Research, Ministry of Education), Jiangxi Normal University, Nanchang, Jiangxi, 330022, China

²Graduate School of Jiangxi Normal University, Nanchang, Jiangxi, 330022, China

Abstract. Currently, little attention was paid to the tourism's CO₂ emission (CE) at province level. Thus, taking Hainan as a case, we computed this province's CE, and analyzed the relationship between Hainan's tourism economy and its CE, and the drivers of the CE. The results showed that Hainan's tourism CE increased rapidly from 99.88×10^4 t in 2001 to 475.07×10^4 t in 2015. Particularly, Tourism transport always accounted for the largest proportion of tourism CE (more than 74%). Moreover, Hainan presented a holistic weak decoupling (0.68) during 2001-2015. But the decoupling rate was only 57.14%. Thus, Hainan still has much potential to improve the energy-use efficiency of tourism industry for accelerating the decoupling process. In addition, the effect of population was the dominant driver to promote Hainan's tourism CE followed by expenditure size effect with the contribution rates of 132.52% and 11.78%, respectively. Whereas energy intensity effect played the most primary role in inhibiting CE followed by industrial structure effect, and their contribution rates were -38.65% and -5.58%, respectively. Last, based on these results above, some reasonable countermeasures and suggestions are proposed.

1 Introduction

Currently, global warming or climate change has deeply exerted obvious influence on the environment [1]. Thus, more efforts should be taken to mitigate the corresponding greenhouse gas, such as the carbon dioxide (CO₂) emissions. The CO₂ emissions (CE) are mainly produced by burning fossil fuels (e.g. coal, oil, gas). In particular, tourism has become the industry with the largest number of participants among many developed and developing countries [2]. Such a huge human activity will inevitably consume quantities of energies and produce the corresponding emissions which, in turn, go on impairing environment and aggravating global warming [3]. So, it is necessary and imperative to comprehensively study the related issues of tourism's CE.

In reality, China's economic sectors including the tourism industry could not further develop without energy resources. But energy consumption (EC) will inevitably lead to further environmental pollution and rise of carbon emissions. Therefore, how to coordinate the economic growth and environmental protection should be scientifically made clearer, especially in tourism industry. Wu and Shi (2011) used a bottom-up method to systematically estimate the whole China's tourism CE [4]. Then, using the same method, Tang et al. (2018) estimated the tourism-related CO₂ emissions in China from 2000-2015, the results showed the highest tourism-related CO₂ existed in eastern coastal China,

while the least was in the west of China [5]. Moreover, Kuo and Chen (2009) adopted a life cycle assessment approach to study the energy use, the corresponding CE, as well as some other environment influences caused by tourism in Taiwan's island [6]. In addition, Chen et al. (2018) introduced the Tapio decoupling index and Logarithmic Mean Divisa index (LMDI) to reveal the relationship between tourism economic growth and tourism CE in Yangtze River Delta [7].

Although people have performed such fruitful studies, these studies most focused on national perspective. In other words, the studies at the province's level are little. Moreover, few cases have analysed the nexus between tourism economy and its CE, meanwhile, studied the drivers of tourism CE as well. Thus, the two works have been simultaneously studied in this paper, which has a certain innovation. First, taking Hainan as the case study, we assess the nexus and decoupling process between the tourism economy and its tourism CE; second, we use the LMDI model to further analysis the underlying drivers of the tourism's CE.

2 Data and Methodology

2.1 Data description

The data are collected from the Yearbook of Hainan Statistics (2002-2016), the Yearbook of China Tourism Statistics (2002-2016), the sample survey information of

* Corresponding author: jiaaniu@126.com

inbound tourists and China’s domestic tourism (2002-2016) and China’s tourism statistical bulletin (2002-2016).

It should be noted that China’s government has promulgated a series of plans for national economic and social development every five years since 1953, namely, “Five-Year Plan (FYP)”. To make the related analysis and results clearer, here, we subdivided the time into three stages, 2001-2005 (10th FYP), 2006-2010 (11th FYP), and 2011-2015 (12th FYP).

2.2 Methodology

The bottom-up method used to computer Hainan’s tourism EC and CE is from the article [4]. The Tapio decoupling indicator is from the article [8], and the LMDI is from the article [1].

3 Results and analysis

3.1 Dynamics of Hainan’s tourism EC and CE

Figure 1 showed the total tourism CE and EC during the period 2001-2015 in Hainan. The percentages of the sub-sectors (tourism transport, tourism accommodation and tourism activities) were presented in Figure 2.

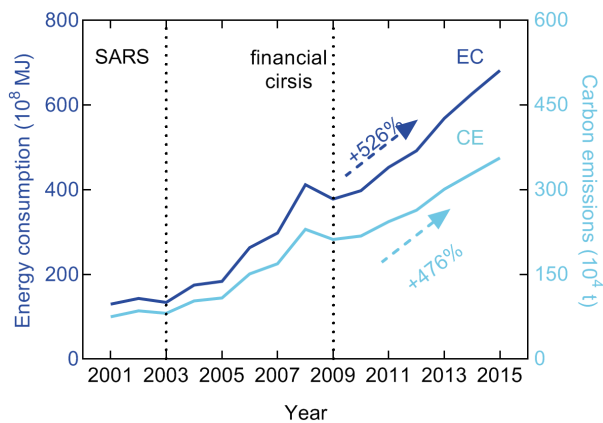


Fig. 1. Tourism EC and CE

It could be easily seen that the tourism EC in Hainan was 129.56×10^8 million J (MJ) in 2001 (Fig. 1). Then, the EC experienced a steady increase to 681.73×10^8 MJ in 2015, which was over 5.26 times than that in 2001. Thus, an overall increasing trend existed in Hainan’s EC, which has an annual growth amount of 39.44×10^8 MJ and rate of 12.59%. However, Hainan’s tourism EC waned -6.30% in 2003 and -8.27% in 2008, respectively. The phenomena might arise from the outbreaks of the Severe Acute Respiratory Syndromes (SARS) in 2003 and the financial crisis in 2008, which brought a huge shock to the tourism industry all over the world (including Hainan). The tourism transport played the most significant role in the total tourism EC, and it accounted for more than 86% all the time between 2001 and 2015. According to the dynamics of total tourism EC in Hainan, it could be divided into two phases: the proportion of tourism transport fluctuated from 90.18%

in 2001 to 88.29% in 2005, and then continuously enlarged the proportion to the summit (96.58%) in 2015. With respect to the tourism accommodation EC, it was from 11.26×10^8 MJ in 2001 to 26.57×10^8 MJ in 2008, then declined to 13.73×10^8 MJ in 2015. Despite the continual augment of tourism activities, the increase amount of corresponding EC was considerably small. It increased from 1.46×10^8 MJ to 9.60×10^8 MJ, with an annual growth amount of 0.58×10^8 MJ during 2001-2015. Therefore, it could be concluded that Hainan should pay more attention to optimizing the tourism transport section and formulating more reasonable policies or measures to reduce the related transport’s energy consumption.

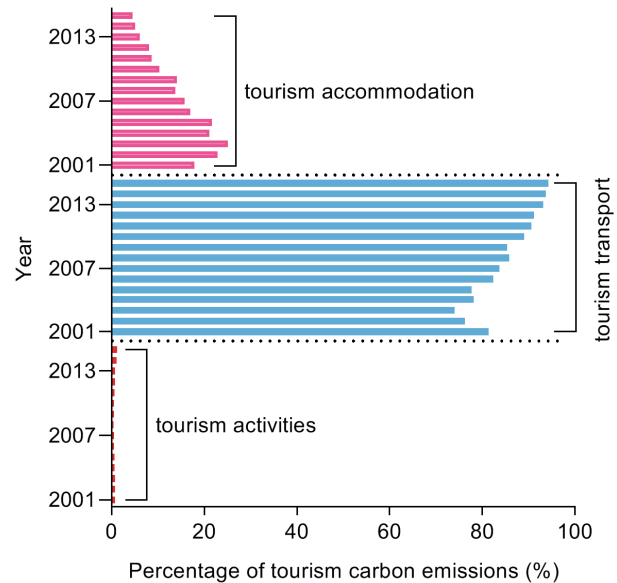


Fig. 2. Percentage of Tourism three sub-sectors’ CE

Similarly, the trajectory of the tourism CE in Hainan was basically consistent with the tourism EC. The tourism CE in Hainan increased from 99.88×10^4 tonnes (10^4 t) in 2001 to 475.07×10^4 t in 2015 respectively, with an annual growth amount of 26.80×10^4 t and rate of 11.78%. The obviously negative growth was -4.91% in 2003 and -7.96% in 2009, which was consistent with the EC’s change. From three sub-sectors’ percentage of tourism CE (Fig. 2), we could easily see that tourism transport emitted the largest proportion of the total tourism CE in Hainan. Overall, tourism transport accounted for no less than 74%, a very high share, of total tourism CE. Besides, it should be noteworthy that the percentage of tourism transport’s CE increased constantly during 2006-2015 (11th-12th FYP), then reached to the summit (94.24%) in 2015. In contrast, the percentage of tourism accommodation’s CE experienced an opposite change: the proportion of tourism accommodation’s CE was from 17.87% in 2001 to 21.62% in 2005, then encountered a continuous decline to 4.58% in 2015. As for the tourism activities’ CE, it usually only occupied few shares of the tourism CE (<1.2%).

3.2 Decoupling analysis

As shown in Table 1, Hainan experienced five different types of decoupling states (strong decoupling, weak decoupling, recessive decoupling, expansive coupling and expansive negative decoupling) during the period 2001-2015. Thus, it could be said that Hainan's tourism experienced a complicate development process. On the whole, the decoupling indicator of Hainan's tourism was 0.68 from 2001 to 2015. That is to say, Hainan's tourism industry had achieved holistic weak decoupling, which indicated its tourism revenues increased a little faster than the CE. This is the ideal situation expected by us. The decoupling value approached to the critical value (0.8), which implied Hainan's decoupling quality was not desirable. In fact, Hainan's tourism economy failed to decouple from CE in most years. From each year's decoupling status, Hainan's decoupling rate was just 57.14%. However, Hainan still had great potential, because we could find a desirable tendency of the decoupling state after the financial crisis.

During the 10th FYP (2001-2005), the relationship between tourism economy and its CE was not desirable with the expansive coupling (1.06). The expansive negative decoupling existed during 2001-2002 and 2003-2004. This meant the growth of tourism CE was higher than tourism revenues and might be explained by Hainan positioned the development as the top priority but neglected the environmental protection so that its economy was low energy efficiency. In addition, Hainan's tourism industry showed recessive coupling in 2002-2003. That was because China burst out the SARS in 2003 and it brought negative influence on China's tourism industry, including Hainan. For this reason, Hainan's tourism revenues declined by 1.9%.

Table 1. Decoupling index and state of Hainan's tourism industry during 2001-2015

	Period	Index	State
10 th FYP (2001-2005)	2001-02	1.63	Expansive negative decoupling
	2002-03	2.56	Recessive decoupling
	2003-04	1.45	Expansive negative decoupling
	2004-05	0.41	Weak decoupling
	2001-05	1.06	Expansive coupling
11 th FYP (2006-2010)	2005-06	2.97	Expansive negative decoupling
	2006-07	0.58	Weak decoupling
	2007-08	2.95	Expansive negative decoupling
	2008-09	-0.79	Strong decoupling
	2009-10	0.14	Weak decoupling
	2006-10	0.54	Weak decoupling
12 th FYP (2011-2015)	2010-11	0.45	Weak decoupling
	2011-12	0.49	Weak decoupling
	2012-13	1.09	Expansive coupling
	2013-14	0.51	Weak decoupling
	2014-15	0.65	Weak decoupling
	2011-15	0.61	Weak decoupling
Whole	2001-15	0.68	Weak decoupling

During the 11th FYP (2006-2010), the nexus between tourism revenues and its CE turned to weak decoupling

(0.54). At this stage, Hainan's tourism revenues and its CE increased with an annual average growth rate of 16.18% and 9.69%, respectively. Undoubtedly, Hainan's tourism was deeply affected by the financial crisis in 2008. Therefore, the tourism was in expansive negative decoupling during 2007-2008. In addition, China's government took some powerful measures to stimulate economy, so that strong decoupling and weak decoupling reoccurred in sequence during 2008-2010.

During the 12th FYP (2011-2015), Hainan's tourism revenues rose with an annual average rate of 12.06%, meanwhile, Hainan's government paid more attention to environmental protection. Thus, Hainan's tourism still maintained the weak decoupling (0.61). Although the decoupling value was higher than that in the 11th FYP (0.54), its tourism decoupling status was more stable. Apart from expansive coupling in 2012-2013, all the remaining years were weak decoupling. This phenomenon was echoed with whole China's economy.

3.3 Drivers of CE's Changes at three stages

Based on the LMDI model mentioned above, the additive decomposition results of drivers were expressed in Figures 3. It could be easily seen that the four drivers (industrial structure, energy intensity, expenditure size and population) totally contributed 285.52×10⁴ t tourism CE during 2001-2015. The effect of population was the most primary driver to the CE's growth, it increased nearly 378.36×10⁴ t tourism CE during 2001-2015. Expenditure size also exerted a positive influence on promoting the tourism CE, and it created 33.63×10⁴ t tourism over the entire period. The effect of energy intensity was the most significant driver, which acted to decrease emissions by 110.35×10⁴ t. In addition, industrial structure inhibited the tourism CE, and reduced tourism CE by 15.94×10⁴ t over 2001-2015.

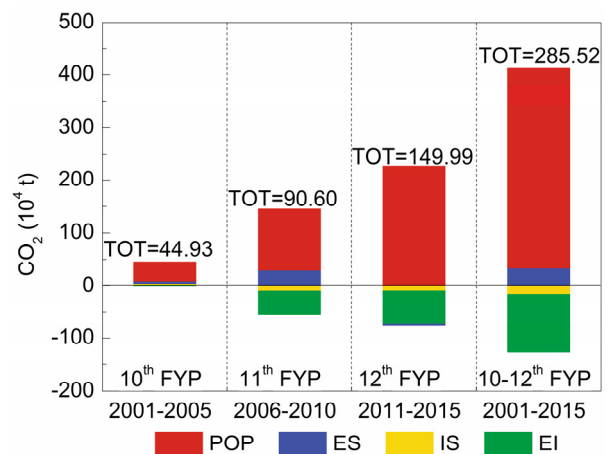


Fig. 3. Additive decomposition results for Hainan's tourism at various stages (POP, ES, IS, EI represent population, expenditure size, industrial structure, energy intensity, respectively, and TOT= POP+ES+IS+EI)

From 2001 to 2015, the contribution rates of these four drivers were 132.52% (population growth effect), 11.78% (expenditure size effect), -38.65% (energy intensity effect) and -5.58% (industrial structure effect),

respectively. The total promotion effect ($147.30\% = 135.52\% + 11.78\%$) was more than that total reduction effect ($-44.23\% = -38.65\% - 5.58\%$). So, overall, these effects led to a 103.07% increase in the total CE over the studied time.

Population effect always had a positive influence on the tourism CE growth, and its contributions for increasing CE were 36.07×10^4 t, 115.61×10^4 t and 226.68×10^4 t in the 10, 11 and 12th FYP, respectively. The growth speed was fast. For instance, the number of tourists and the tourism revenues were 53.36 million and 57.25 billion in 2015, which was 4.74 times and 6.51 times than that in 2001, respectively. These implied the scale of Hainan's tourism industry continuously expanded, and it inevitably caused the increase of tourism CE. Obviously, tourism transport occupied the biggest share of the tourism CE. Hence, with the development of Hainan's tourism industry, the effect of population triggered 338.53×10^4 t CE, nearly 89.5% of the total CE (378.36×10^4 t). In addition, the tourism accommodation and activities totally led to 36.77×10^4 t and 3.05×10^4 t, but their growth rates were slow. This also verified the above analysis in Figure 2.

Expenditure size effect was another important driver to promote CE's growth. Its contribution for increasing CE was totally 33.63×10^4 t during 2001-2015. It was noteworthy that a positive effect on tourism CE could be found in the stage of 2001-2010, while a negative effect emerged during 2011-2015. However, overall, the expenditure size effect was positive in the studied period.

However, energy intensity effect was the key factor to inhibit the tourism CE. Its contribution for reducing tourism CE was 110.35×10^4 t CO₂ during 2001-2015. Especially, the CE's decrease speed due to energy intensity effect was faster in the later time. This was because most of China's districts (including Hainan) improved their energy-use efficiency to mitigate carbon emissions during 2006-2015. Robust evidence could also be found in the tourism's three sub-sectors. The energy intensity effects of tourism transport, accommodation and activities resulted in -38.76×10^4 t, -5.97×10^4 t, and -0.26×10^4 t, respectively. Thus, the energy intensity effect of tourism transport played a significant role in declining CE. Similarly, the contributions of industrial structure effect were -15.94×10^4 t in 2001-2015, indicating that industrial structure was also a factor of reducing the tourism CE. Specifically, the changes of the CE caused by tourism transport, tourism accommodation and tourism activities were 10.88×10^4 t, -28.77×10^4 t and 1.96×10^4 t over 2001-2015.

4 Conclusions

Based on the data of 2001-2015 of Hainan province, we applied the bottom-up method to computer the total EC and CE of Hainan's tourism. Then, using the Tapio index (LMDI model), we analyzed the decoupling nexus between tourism economy and the matching CE (the drivers of CE).

The results showed that Hainan's CE increased rapidly from 99.88×10^4 t in 2001 to 475.07×10^4 t in 2015,

and its EC grew from 129.56×10^8 MJ to 681.73×10^8 MJ during 2001-2015. Particularly, tourism transport always accounted for more than 74% tourism CE during 2001-2015. The decoupling index suggested that Hainan presented a holistic weak decoupling (0.68) during 2001-2015. But the decoupling rate was only 57.14%. Thus, Hainan still has much potential to improve the energy-use efficiency of tourism industry for accelerating the decoupling process. The contributions of the population effect, expenditure size effect, energy intensity effect and industrial structure effect were 378.36×10^4 t, 33.63×10^4 t, -110.35×10^4 t and -15.94×10^4 t, respectively. The results indicated that the effect of population was the most significant driver of CE growth followed by expenditure size effect. However, energy intensity effect played the most primary role in habiting CE followed by industrial structure effect.

According to these results above, the following countermeasures could be put forward to help the low-carbon tourism development in Hainan. First, to achieve energy savings and emission reduction in the long run, Hainan should lower the tourism transport CE, especially the airplanes' CE. Thus, Hainan should take some effective policies or countermeasures to optimize the structure of tourism transport. Second, the government should make efforts to provide some low-carbon travel routes and advocate tourists to strengthen the awareness of environmental protection. Third, the energy intensity had an obvious negative effect on tourism CO₂ emissions. Therefore, Hainan should invest more in related R&D business and accelerate the pace of innovation to improve energy efficiency to cut down the corresponding tourism CE.

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