Annals of Tourism Research 69 (2018) 18–30

Contents lists available at ScienceDirect

Annals of Tourism Research

journal homepage: www.elsevier.com/locate/annals

Carbon tax, tourism CO_2 emissions and economic welfare

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ARTICLE INFO

Keywords:
Carbon dioxide emissions
Economic welfare
Low-carbon tourism
Carbon tax
Computable general equilibrium modelling

ABSTRACT

This paper, using a computable general equilibrium model, presents a simulation study of the changes in carbon emissions and economic welfare which could be brought about through a carbon tax policy in China's tourism industry. Our results clearly indicate that a carbon tax policy could have a remarkable impact on tourism-related carbon emissions and economic welfare. In addition, we find those impacts would be significantly different at different times. Also, the impacts of different carbon taxes on the different sectors of the tourism industry are also quite different. Furthermore, our analysis highlights three key managerial recommendations that are relevant for Chinese tourism policy-makers. Our results also have a certain reference value for the management of other low-carbon tourism destinations.

Introduction

The general public accepts that carbon dioxide (CO_2) emissions are causing global climate change (Cox, Betts, Jones, Spall, & Totterdell, 2000; Figueroa, Fout, Plasynski, Mcilvried, & Srivastava, 2008; Friedlingstein et al., 2006). In response to this climate change, numerous countries and regions have introduced climate-related policies that influence legislation, taxation, and the market. The carbon tax has been considered as an effective instrument to contain the increasing CO_2 emissions and to prevent economies from becoming locked in carbon-intensive pathways (Calderón et al., 2015; Dulal, Dulal, & Yadav, 2015; Pereira, Rui, & Rodrigues, 2016). In the current context that suggests carbon tax implementation as a tool to curb climate change, tourism and the tourism economy face a novel challenge. Consequently, this study uses the tourism power China as a case study to investigate the impacts of carbon tax on the tourism-related CO_2 emissions and economic welfare. The main research method employed for this study is a computable general equilibrium model (CGE), which is widely used in policy simulations. The main contribution of this study is the presentation of a first attempt to simulate the impacts of different carbon taxes on tourism-related CO_2 emission levels. This study simultaneously considers both the overall and specific tourism economic welfare changes in respect of added value and employment. In addition, this study investigates carbon tax impacts at different times and under different carbon tax scenarios. This enables a more flexible policy and results in a more thorough empirical research.

The Davos Declaration estimate tourism to contribute approximately 5% of the global CO_2 emissions (World Tourism Organization (UNWTO) and United Nations Environment Program (UNEP), 2008). As such, tourism is also expected to be at the forefront of the global response to climate change (UNWTO, 2007). Consequently, the entire tourism industry has become an important component of greenhouse gas emissions, energy conservation, and emission reduction. Therefore, the tourism industry has obtained important significance in achieving global emission reduction targets and a large number of studies have focused on reducing tourism-related CO_2 emissions. These studies have been conducted from different perspectives, all of which can be summarized to deal with the following aspects of CO_2 emission reductions: technical developments (Jones, 2013; Walz et al., 2008),

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https://doi.org/10.1016/j.annals.2017.12.009
Received 17 August 2017; Received in revised form 20 December 2017; Accepted 26 December 2017
0160-7383/

voluntary approaches (Eijgelaar, 2011; Gössling et al., 2007; Horng et al., 2014; Mair, 2011; Scott, Peeters, Gössling, Scott, & Becken, 2010), comprehensive framework discussions (Horng, Hu, Teng, & Lin, 2012; Hu, Jeoushyan, Teng, & Shengfang, 2013; Peeters, Gossling, & Williams, 2006; Zhou, Wang, Yu, Chen, & Zhu, 2016), and policy implementations. In terms of policy implementations, several studies have extended our understanding of the impacts of carbon tax on tourism CO_2 emissions.

For example, Mayor and Tol (2007) explore the impacts of carbon tax on aviation carbon emissions and visitor numbers under different scenarios. Cranenburgh, Chorus, and Wee (2014) suggest the ongoing debate regarding aviation carbon taxes as a viable measure to reduce aviation carbon dioxide emissions. The authors further evaluated the effects of high aviation carbon taxes on tourism-related CO_2 emissions. Due to the significant amount of CO_2 emissions caused by air transportation, scholars generally tend to focus more on the impact of carbon taxes on air transport-related emissions (e.g. Cranenburgh et al., 2014; Mayor & Tol, 2007). However, few studies have contributed to an understanding of the comprehensive impact of carbon taxes on the tourism industry as a whole.

Several studies have investigated how carbon tax (or carbon pricing policies) affect economic changes with respect to tourism or the tourism sectors. For example, Tol (2007) conclude that travel behavior would only be slightly affected by carbon taxation of aviation fuel. The number of tourists would significantly be affected by levying carbon-related air passenger duties (Mayor & Tol, 2007) and other climate policy instruments (Mayor & Tol, 2010). These studies all focus on the impact of carbon tax from the perspective of tourists, while the "economy" property is not prominent. Dwyer, Forsyth, and Spurr (2012) and Dwyer, Forsyth, Spurr, and Hoque (2013) explore the potential impact of a carbon tax on the Australian tourism economy; and Meng and Pham (2017) analyze the impact of a carbon tax on the Australian tourism economy. Dwyer et al. define tourism sectors based on the Tourism Satellite Account, while the study of Meng and Pham focus on input–output tables. Both studies apply different research methods and acquired different data, thus leading to significantly different simulation results.

In China, the contribution of tourism to the national CO_2 emissions of all industries in 2002, 2005, 2007, and 2010 were approximately 2.489%, 2.425%, 2.439%, and 2.447%, respectively (Meng, Xu, Hu, Zhou, & Wang, 2016). The indirect carbon emissions of the tourism industry (except for the transport sector) have been reported to be three to four times that of their direct CO_2 emissions (Meng et al., 2016). Compared to global levels, China's tourism-related CO_2 emissions account for a smaller proportion of overall industrial emissions. However, due to China's enormous level of carbon emissions (approximately 9.123 billion tons in 2016, accounting for 27.3% of the emissions of the entire world according to the BP Statistical Review of World Energy for June 2017), even if only approximately 2.5% of the overall proportion of emissions would be accounted for, this would still mean that the tourism industry is responsible for a considerable amount of CO_2 emissions (approximately 0.228 billion tons in 2016). Furthermore, the Chinese tourism industry is developing rapidly (with an average annual growth rate of the tourism revenue of approximately 21.57% from 2010 to 2016, according to the National Tourism Administration of the People's Republic of China (2017)). This in turn indicates that the CO_2 emissions of the Chinese tourism industry are increasing more rapidly than the average global level.

Despite not having been implemented so far, the carbon tax has also been advocated as an effective and efficient complementary measure, and could thus be implemented to support the future low-carbon development of China (Asian Development Bank, 2015; Chen & Nie, 2016; Dong et al., 2017; Liu & Lu, 2015). Zhang (2017) discusses the importance of a carbon tax for the development of low-carbon tourism destinations. Furthermore, the Climate Division of China's National Development and Reform Commission reported the launch of a study on the introduction of carbon taxes in 2020 (People.cn., 2016), thus making it is very likely that a levy tax will soon be introduced in China. Based on this, an increasing number of studies have been devoted to assessing the impact of such a Chinese tax on related CO_2 emissions (Dong et al., 2017; Fang, Tian, Fu, & Sun, 2013; Xiao, Niu, & Guo, 2016). In addition, reports have been published on the impact of Chinese economic welfare. For example, Lu, Tong, and Liu (2010) use a dynamic recursive general equilibrium model to explore the impact of carbon tax on the Chinese economy. Guo, Zhang, Zheng, and Rao (2014) quantify the impacts of different carbon emission reduction scenarios on the GDP, income, the price of labor, investments, and savings. The authors investigate changes in energy sector outputs and confirmed the potentially negative impact of a carbon tax on economic growth.

As a means of taxation, the carbon tax has significantly impacted CO_2 emissions and economic welfare. However, few studies explicitly investigate these effects for the tourism industry, nor for the Chinese tourism industry in particular despite its important economic role in China and worldwide. Recognizing the impact of a carbon tax policy on the Chinese tourism industry and understanding the management implications of such impacts deserves further study. Unfortunately, to date, few studies have examined changes of the Chinese tourism under different carbon tax scenarios; therefore, this is the focus of this paper. Furthermore, because China's carbon tax has not yet been levied and consequently, the tax rate has not been determined, it is important to investigate different targeted tax rates and compare the resulting impacts. It is also of practical significance to examine the resulting impacts at different points in time, since levying a carbon tax is a long-term dynamic process. For that reason, this paper proposes a comprehensive dynamic analysis framework to explore the impacts of different tax rates at different time points on China's tourism industry in terms of CO_2 emissions, carbon intensity, value added and employment. Relevant time points are i.e. the year 2020 (when carbon intensity must be reduced from 40 to 45%, relative to 2005 levels) and the year 2030 (when national CO_2 emissions will reach their peak).

The remainder of this study is organized as follows: Section "Methodology" presents the methodology drawing on the computable general equilibrium model (CGE), the Social Account Matrix (SAM), and the determination of tourism-related industries. Section "Results and discussion" provides the results and a thorough discussion of our findings. Our conclusions and policy implications are presented in Section "Conclusions and policy implications", along with suggestions for future research.

Methodology

The CGE model plays an important role for estimating the economic impacts of tourism shocks and for tourism policy formulation (Dwyer, 2015), which is also confirmed by Meng, Siriwardana, and Pham (2013), Inchausti-Sintes (2015), Pham, Jago, Spurr, and Marshall (2015), and Pratt (2015). Considering the wide applicability of CGE models in tourism policy simulations, this study adopts this model to explore the impacts of carbon taxes on Chinese tourism.

Social accounting matrix

For the construction of a CGE model, the basic work is the preparation of a social accounting matrix (SAM), as this is an important form of data organization in a CGE model. Therefore, creating a SAM directly related to the Chinese tourism industry is a precondition of our study.

Based on the System of National Accounts, a SAM expands a standard input–output table and comprehensively, flexibly, and in great detail describes the structure of an economic system in a region or an entire country for a particular year. Since the CGE model requires a complete data set that contains production, income distribution, and consumption as base year data, and because all that information can be obtained from a SAM, we use SAM for our CGE modeling.

Since this paper examines the potential impacts of carbon taxation on tourism, it is central to properly define the tourism industry in the SAM. In China's input–output table, the tourism industry is not separate and therefore, a definition of tourism-related industries is first required. The UNWTO suggested the “Standard International Classification of Tourist Activities (SICTA)”, which divides tourism-related industries into two types: industrial sectors that completely belong to tourism, and industrial sectors that only partly belong to tourism. However, this classification is vague, and it is often difficult to fully grasp the extent of an industry’s “dependence” or “belonging”. A classification that is more widely accepted by scholars has been presented in the Tourism Satellite Account: Recommended Methodological Framework 2008 (TSA: RMF 2008), as suggested by the UNWTO. In the TSA: RMF 2008, the UNWTO classifies three types of tourism industries: 1) tourism characteristic industries, 2) tourism connected industries, and 3) other industries (United Nations, 2010). This method of division has since been approved by an increasing number of scholars and given the popularity of the TSA, it is very suitable for modeling a CGE.

Unfortunately, until now no national TSA has been defined for China. The NBSPRC (2015) published the “Statistical Classification of National Tourism and Related Industries (2015)” (SCNTRI), which is based on “The National Economy Industry Classification (GBT4754-2011)” (NBSPRC, 2011) and the “International Recommendations for Tourism Statistics, 2008, Compilation Guide (IRTS 2008 Compilation Guide) (Unedited Draft Version)” (UNWTO, 2014). In the SCNTRI, China's tourism industry has been divided into the following eight classifications: 1) transport, 2) food and beverage, 3) scenic locations, 4) tourism shopping, 5) tourism entertainment, 6) tourism integrated services (including travel agencies and tourism plans), 7) tourism support services (including finance and education), and 8) government tourism management services. However, these classifications do not match the entries in the input–output table and are thus not adaptable to our SAM. Taking this into account, and mainly based on the 2012 Chinese input–output table, but with reference to TSA: RMF 2008, IRTS 2008, NBSPRC (2015) and NBSPRC (2011), this study classifies the tourism-related industries in China as shown in Table 1. Our classifications take the actual practices of Chinese tourism into consideration.

The SAM we use in this study consists of 73 sectors (73 activities and 73 commodities) including 14 tourism sectors (as shown in Table 1), two elements (one labor and one capital), one resident, one enterprise, one government subsidy, one extra-system, one government, one rest of the world, one capital account, one stock exchange, and the total.

The SAM data mainly originates from input–output tables. The most recent Chinese input–output table is the 2012 table (National Economy Accounting Department of National Bureau of Statistics of the People's Republic of China, 2015) and was used in this model. The year 2012 was used as base year. Further SAM data with respect to government consumption, import tariff, government production tax, government subsidy, receipts tax, government debts revenue, and government payment to foreign countries is obtained from the Finance Yearbooks of China 2013 (Editorial Committee of Finance Yearbook of China, 2013), element-capital, resident's foreign income, and the government foreign transfer income from the China Statistical Yearbooks of 2013 (Bureau of Statistics of the People's Republic of China (NBSPRC), 2013a). The CO_2 emissions and employment data are obtained from the China Energy Statistical Yearbooks of 2012 (NBSPRC, 2013b) and the China Population & Employment Statistics Yearbook 2012 (NBSPRC, 2013c),

Table 1
Tourism characteristic and connected industries in China.

Number	Tourism characteristic industries	Number	Tourism connected industries
I_1	Transport via railway	I_7	Manufacture of alcohol and beverages
I_2	Transport via road	I_8	Manufacture of other food products
I_3	Water transport	I_9	Manufacture of transport equipment
I_4	Air transport	I_{10}	Business services
I_5	Accommodation	I_{11}	Food and beverage services
I_6	Amusement and recreation activities	I_{12}	Management of water, conservancy, environment and public facilities
		I_{13}	Culture, art and entertainment activities
		I_{14}	Sports activities

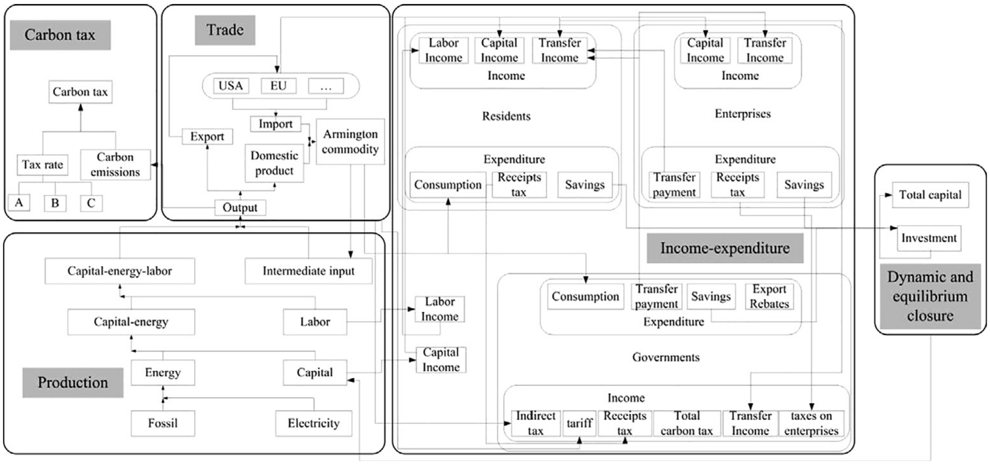

Fig. 1. Framework of the CGE model.

respectively.

During the process of creating a SAM and due to the different data sources, some data inconsistency may occur. This paper uses the Cross Entropy approach to smooth those data, thus obtaining a target SAM table that is very close to the initial table. In this paper, a dynamic recursive CGE model is constructed based on the 2012 data.

Description of the computable general equilibrium model

The CGE model used in this paper is subdivided into five modules: 1) production, 2) trade, 3) carbon tax, 4) income expenditure, and 5) dynamic and equilibrium closure. The total framework of our developed CGE is shown in Fig. 1, where "A", "B", and "C" refer to different carbon rates.

The production module describes the assembly of different production factors in the economic system, which is used to arrive at the final output. A five-level production function is used in the production block.

The first level: Various forms of fossil energy are added, using the production function with constant elasticity of substitution (CES) to create a fossil energy input named $FOSSIL_{i,t}$, see Eq. (1):

$$FOSSIL_{i,t} = \left(\sum_{fossil_f} a_{fossil_{f,i}} FOSSILF_{fossil_{f,i,t}}^{\rho_f}\right)^{1/\rho_f} \tag{1}$$

where $\sigma_f = 1/(1-\rho_f)$ represents the elasticity of substitution of different fossil energy, $a_{fossil_{f,i}}$ represents the share of various energy, and$\sum_{fossil_f} a_{fossil_{f,i}}$=1.

The second level: $FOSSIL_{i,t}$ is added to electricity $ELE_{i,t}$, using CES to obtain the energy input named $Energy_{i,t}$.

The third level: $Energy_{i,t}$ is added to the capital input $K_{i,t}$, using CES to obtain the capital-energy input named $(K-E)_{i,t}$.

The fourth level: $(K-E)_{i,t}$ is added to the labor input $L_{i,t}$, using CES to obtain the capital-energy-labor input named $(K-E-L)_{i,t}$. Furthermore, intermediate inputs from different industries are added, using the Leontiff production function to obtain the total intermediate input named $TOTInt_{i,t}$

$$TOTInt_{i,t} = min\left(\frac{Int_{1,i,t}}{a_{1,i}}, \frac{Int_{2,i,t}}{a_{2,i}}, \cdots, \frac{Int_{n,i,t}}{a_{n,i}}\right) \tag{2}$$

Here, $Int_{1,i,t} (j = 1,2,3,\ldots,n)$ represents the intermediate input from thejthsector to the ithsector at the time t and $a_{j,i}$ represents the input–output coefficient.

The fifth level: $X_{i,t}$, the output of the ithsector at the time t, is obtained by adding $TOTInt_{i,t}$ and $(K-E-L)_{i,t}$ using CES, see Eq. (3):

$$X_{i,t} = \left(a_{int,i}\mathrm{TOTInt}_{i,t}^{\rho_x} + a_{k-e-l,i}(\lambda_{k-e-l,i,t}(K-E-L)_{i,t})^{\rho_x}\right)^{1/\rho_x} \tag{3}$$

Here, $\sigma_x = 1/(1-\rho_x)$represents the elasticity of the substitution of $TOTInt_{i,t}$ and $(K-E-L)_{i,t}$, $a_{int,i}$ and $a_{k-e-l,i}$ represent the share of those two types of input, and $\lambda_{k-e-l,i,t}$ represents the total factor efficiency coefficient that expresses technical progress.

In this study, the elasticities of the factor substitution in the production function at different levels are shown in Table 2.

This trade module reflects the trade relationship between China and foreign countries. When adding the product, an incomplete substitution relationship between the commodities in different countries or regions is typically assumed. The imported commodities are also added via CES. In addition, exported commodities are added using the function with constant elasticity of transformation. The domestic aggregated demand $Q_{i,t}$ consists of the domestic production $D_{i,t}$ and the imported commodities $M_{i,t}$. The aggregate

Table 2
Elasticities of substitution in the CGE model.

Level	Elasticities of substitution
The first level of fossil energy	1.3 for coal, oil, gas; 1.25 for petroleum processing, coke, electricity, gas; 1.6 for other service industries (including tourism industries), 1.5 for the remaining industries
The second level between the fossil energy and electricity	0.65 for coal, oil, gas; 0.6 for petroleum processing, coke, electricity, gas; 0.9 for other service industries (including tourism industries), 0.7 for the remaining industries
The third level between energy and capital	0.24 for coal, oil, gas; 0.23 for petroleum processing, coke, electricity, gas; 0.28 for other service industries (including tourism industries), 0.23 for the remaining industries
The fourth level between energy, capital and labor	0.2 for agriculture; 0.3 for various energy and mining industries; 0.56 for food and beverage industries; 0.84 for transport industries; 0.63 for the remaining industries

output $X_{i,t}$ consists of the domestic production $D_{i,t}$ and the exported commodities $E_{i,t}$ (see Eqs. (4) and (5)).

$$Q_{i,t} = \left(a_{m,i}M_{i,t}^{\rho_m} + a_{dm,i}D_{i,t}^{\rho_m}\right)^{1/\rho_m} \tag{4}$$

$$X_{i,t} = \left(a_{e,i}E_{i,t}^{\rho_e} + a_{de,i}D_{i,t}^{\rho_e}\right)^{1/\rho_e} \tag{5}$$

Here, $a_{m,i}$ and $a_{e,i}$ represent the share of the imported and exported commodities, respectively; $a_{dm,i}$ and $a_{de,i}$ represent the share of the domestic production; $a_{m,i}+a_{dm,i}=1$, $a_{e,i}+a_{de,i}=1$; $\sigma_m = 1/(1-\rho_m)$ represents the Armington elasticity of the domestic and imported commodities, and $\sigma_e = 1/(1-\rho_e)$ represents the substitution elasticity of the domestic and exported commodities.

The optimal import strategy can be extrapolated by minimizing the costs $PM_{i,t}M_{i,t} + PD_{i,t}D_{i,t}$ under the constraints of Eq. (5). The optimal export strategy can be extrapolated by maximizing sales $PE_{i,t}E_{i,t} + PD_{i,t}D_{i,t}$ under the constraints of Eq. (6), where $PM_{i,t}$, $PE_{i,t}$, and $PD_{i,t}$ represent the import price, export price, and domestic price of commodity i at time t, respectively.

The carbon tax module consists of carbon emission coefficients and the applicable carbon tax policy. To avoid repeated calculations of carbon emissions in our CGE model, we only calculate the carbon emissions that are generated during the production process of each industry. According to the Intergovernmental Panel on Climate Change (IPCC) (2006), the unit carbon emission coefficient of a specific commodity can be calculated through a series of carbon emission conversion factors, using Eq. (6) (see Table 3):

$$C_{e_{i,t}} = \frac{\sum_{f=1}^{6} a_f b_f c_f Fossil_{f,i,t}}{X_{i,t}} \tag{6}$$

Here, $C_{e_{i,t}}$ represents the unit carbon emission coefficient of industry i at time t; $Fossil_{f,i,t}$ represents the f energy demand of industry i at time t; f represents the six types of fossil energy industries (i.e., coal mining and washing industry, oil industry, natural gas industry, petroleum and nuclear fuel processing industry, coking industry and gas production and supply industry), and a_f, b_f, and c_f represent the conversion factor, carbon emission coefficient, and oxidation rate of different energy f, respectively.

The additional cost per unit output caused by the applicable carbon tax policy can be calculated as the carbon tax rate multiplied by the carbon emission coefficient (see Eq. (7)):

$$PXE_{i,t} = PX_{i,t} + \frac{ctax_{i,t}TCO_{2_{i,t}}}{X_{i,t}} \tag{7}$$

Here, $PXE_{i,t}$ and $PX_{i,t}$ represent the commodity prices of industry i at time t both before and after levying a carbon tax, respectively, $ctax_{i,t}$ represents the carbon tax rate, and $TCO_{2_{i,t}}$ represents the total CO_2 emissions of industry i at time t.

The income and expenditure module describes the relationship relevant to income and expenditure between multiple accounts, including factors, businesses, residents, governments, and foreign countries. Factor income is defined by its contribution to the total output. In addition, labor income is defined as the product of labor input and wages and capital income is defined as the product of capital input and capital return rates. Corporate income consists of capital returns and transfer payments from the government.

Table 3
Related coefficients of different forms of energy.

Energy	a_f(Unit: MJ/kg)	b_f (Unit: kg/GJ)*	c_f (Unit: %)
Coal	20.79	26	0.92
Oil	41.87	20	0.98
Gas	38.94	15	0.99
Petroleum processing	43.33	20	0.98
Coke	25.47	25	0.93
Electricity	3.51	0	—

Note: 1 MJ = 10^6J, 1GJ = 10^9J.

Corporate expenditure includes taxes and transfer payments to residents. Resident income originates from labor income, while labor return and transfer payments originate from the government, enterprises, and foreign countries. Resident expenditure includes personal income tax and consumption. Government income originates from tax revenue (including the carbon tax revenue), as well as transfer payments from foreign countries. Government expenditure includes transfer payments to residents and enterprises, as well as consumption and export rebates. Foreign income originates from capital return from China and includes the export income of China. Foreign expenditure includes the payment for imports from China and transfer payments to Chinese residents and governments. The difference between income and expenditure of each subject forms the respective savings.

The dynamic progress of the CGE model is formed through a total factor technical progress, capital, and labor. The technical progress is represented as $\lambda_{k-e-l,i,t}$ and the labor at time t is obtained using Eq. (8):

$$L_t = L_{t-1}(1 + grl_t) \tag{8}$$

Here, L_t, and L_{t-1} represent the total labor at time t and $t-1$, respectively; grl_t represents the growth rate of labor at time$t$.

Assuming that the capital return rate depends on the monetary policy in the long run, the capital stock is calculated using Eq. (9).

$$K_t = (1-\delta)K_{t-1} + I_t \tag{9}$$

Here, K_t, and K_{t-1} represent the total capital stock at time t and $t-1$, respectively; I_t represents the total investment at time t, and δ represents the capital depreciation rate.

The CGE model closure consists of three aspects: 1) the foreign savings are endogenous and the exchange rate is exogenous. 2) The fiscal surplus or deficit are endogenous and the tax rate is exogenous. 3) The total investment equals the total savings.

Carbon rate scenarios

To compare the policy effects, we set two scenarios. One forms the baseline scenario, where the carbon tax of the tourism industry is 0. The baseline projections represent a business-as-usual case, without inclusion of the carbon price in the CGE modeling. We calculate the Chinese tourism CO_2 emissions with an increase of total factor productivity, exogenous increase of the labor force, and changes of the endogenous capital accumulation. The second scenario forms the carbon tax scenario, where we levy a carbon tax on both the tourism industry and other industries in China. Dwyer et al. (2013) assume a carbon tax rate of 25 \$/t-CO_2, while Meng and Pham (2017) suggest a rate of 23 \$/t-CO_2 for the Australian tourism industry. However, Australia is a developed country, but China is a developing country and therefore, the Australian tourism industry has reached a more mature level than the Chinese tourism industry. Consequently, the current tax rates are not appropriate for the situation in China.

A number of published studies have investigated China's carbon tax rate. For example, Wang, Li, and Zhang (2011) suggest that both a high (100 ¥/t-CO_2) and a low tax rate (10 ¥/t-CO_2) could be used. Fang et al. (2013) argue that the best tax levy point for China would range between 17.6 and 17.8 ¥/t-CO_2. Qiao and Wang (2014) suggest three different tax rates for China: 20 ¥/t-CO_2, 50 ¥/t-CO_2, and 80 ¥/t-CO_2. Liu, Wang, Niu, Suk, and Bao (2015) propose that a tax rate between 10 and 30 ¥/t-CO_2 would be both preferable and realistic, especially considering the prevalent company preferences with regard to carbon tax policies in China. In this study, we take the actual degree of China's tourism development into account, as well as the results of these previous studies. We also use three different carbon tax rates for our model: 10 ¥/t-CO_2, 50 ¥/t-CO_2, and 90 ¥/t-CO_2. These three tax rates match three different policies: an economy-preferring policy, a moderate policy, and an environment-preferring policy. Considering that 2030 is the deadline until which China has to fulfill its low-carbon development goals, we used 2016–2030 as the simulation time of our model.

Results and discussion

Impacts on tourism-related CO_2 emissions

Table 4 presents baseline forecast values and policy simulation values for Chinese tourism-related CO_2 emissions. As shown in Table 4, the results of the simulation indicate that, during the simulated period, the tourism industry experiences a reduction in real CO_2 emissions relative to baseline values. In addition, the degree of reduction increases with corresponding increases in carbon tax. Table 4 indicates that implementing a carbon tax will positively impact the reduction of CO_2 emissions for China's tourism industry. It should also be noted that, even when applying the same tax rate, the impact of such a carbon tax on China's tourism-related CO_2

Table 4
Impact of carbon tax on tourism carbon emissions.

	Carbon tax price (¥/t-CO_2)					
	10		50		90	
Year	2020	2030	2020	2030	2020	2030
Baseline forecast (Mt)	1025.468	1360.614	1025.468	1360.614	1025.468	1360.614
Policy simulation (Mt)	1023.757	1358.596	1021.214	1355.657	1018.774	1352.691
Deviations (Mt)	1.711	2.018	4.254	4.957	6.694	7.923
Percentage deviations (%)	0.167	0.148	0.415	0.364	0.653	0.582

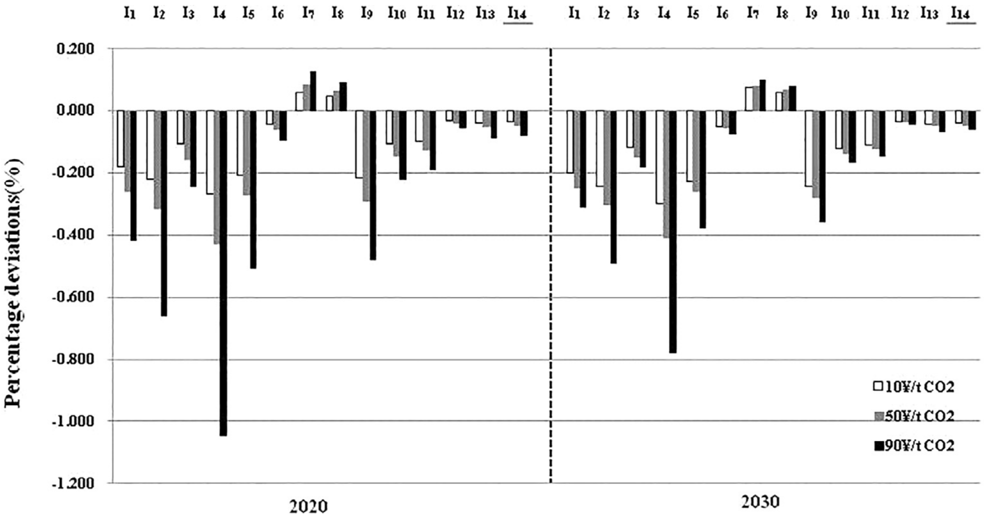

Fig. 2. Changes of carbon emissions in tourism industries.

emissions varies to a small degree for different time points. All three rates exert a stronger impact early during the period from 2016 to 2030. Of course, the absolute volume of carbon emissions increases over time.

Although implementing a carbon tax will reduce the Chinese tourism-related CO_2 emissions, the impacts of carbon taxation on the tourism industry sectors listed in Table 1 (tourism-related industries in SAM) vary largely, as shown in Fig. 2. The results of the simulation indicate that the majority of tourism-related industries in China experience a decrease in their real CO_2 emissions, relative to baseline values. The most negatively affected tourism industries include those that are involved in the production of transport equipment, transport via railway, transport via road, air transport, and accommodation. Furthermore, the impact of different tax rates on different tourism industries also shows a larger degree of difference, especially at a higher tax rate. When levying a rate of 90 ¥/t-CO_2, carbon tax implementation affects air transport the most followed by transport via road, accommodation, the production of transport equipment, and transport via railway. The CO_2 emissions of other sectors are less affected by a carbon tax.

In addition, unlike levying a tax of 90 ¥/t-CO_2, the differences in the impact of carbon taxes on tourism industries are smaller for levying taxes at rates of 50 ¥/t-CO_2 or 10 ¥/t-CO_2. It should be noted that (as shown in Fig. 2), while most tourism industries experience at least a small reduction of their real CO_2 emissions relative to baseline values, some in fact experience an increase. The CO_2 emissions of the alcohol and beverage production and the production of other food products increase by a small amount. Overall, the Chinese carbon tax policy affects tourism accommodation and transport most negatively, while the impact is not significant for the leisure and sports industries. In contrast, the CO_2 emissions of both the food and beverage industries witness an increase under the carbon tax policy.

Numerous studies have shown that the majority of CO_2 emissions in tourism are caused by accommodation and transportation in particular. An increase in carbon emissions means that more tax would be levied in transportation and accommodation if a carbon tax were to be implemented. To reduce operating costs, affected enterprises experience an increased willingness to implement measures to reduce their carbon emissions. Therefore, both industries would be most affected.

Compared to other tourism industries, the CO_2 emissions of the food and beverage industries are lower. However, due to both the implementation and effects of a carbon tax policy, those industries prefer to use lower-priced energy to offset increased operating costs. Although it is clear that the price increase of coal would be more significant than that of oil or gas for the carbon tax mechanism to work, the absolute price of coal per unit of heat still remains comparatively low. The substitution effect between different energies could lead to a shift of food and beverage industries (under a carbon tax scenario) from using oil and natural gas to using coal. However, such a choice would increase CO_2 emissions of these industries. In contrast to these two industries, other tourism industries prefer to reduce CO_2 emissions via technological innovation, thus cutting costs caused by carbon tax. Different options to reduce operating costs under a carbon tax scenario differently impact the CO_2 emissions of the food and beverage industries as well as other tourism industries.

Impacts on tourism carbon intensity

Carbon intensity is a measure for the ratio of CO_2 emissions produced to gross domestic product (GDP). Therefore, tourism carbon intensity is expected to reflect CO_2 emissions per tourism gross added value. For tourism-related CO_2 emissions in China, the results shown in Table 5 indicate that the tourism-related carbon intensity will also decline under the impact of a carbon tax policy. A higher tax rate will lead to a more significant decline. Furthermore, the negative impacts of a carbon tax on the Chinese tourism-related carbon intensity will become more and more notable.

The impacts of a carbon tax on the carbon intensity of Chinese tourism-related industries by the years 2020 and 2030 are shown in Fig. 3. The results of the simulation indicate that the majority of tourism industries experiences a decline in their carbon intensity

Table 5
Impacts of carbon tax on tourism carbon intensity.

	Carbon tax (¥/t-CO$_2$)					
	10		50		90	
Year	2020	2030	2020	2030	2020	2030
Baseline forecast (t/¥10,000)	0.872	0.738	0.872	0.738	0.872	0.738
Policy simulation (t/¥10,000)	0.871	0.737	0.869	0.735	0.867	0.734
Deviations (t/¥10,000)	0.001	0.001	0.003	0.003	0.005	0.004
Deviations (%)	0.135	0.138	0.335	0.353	0.519	0.527

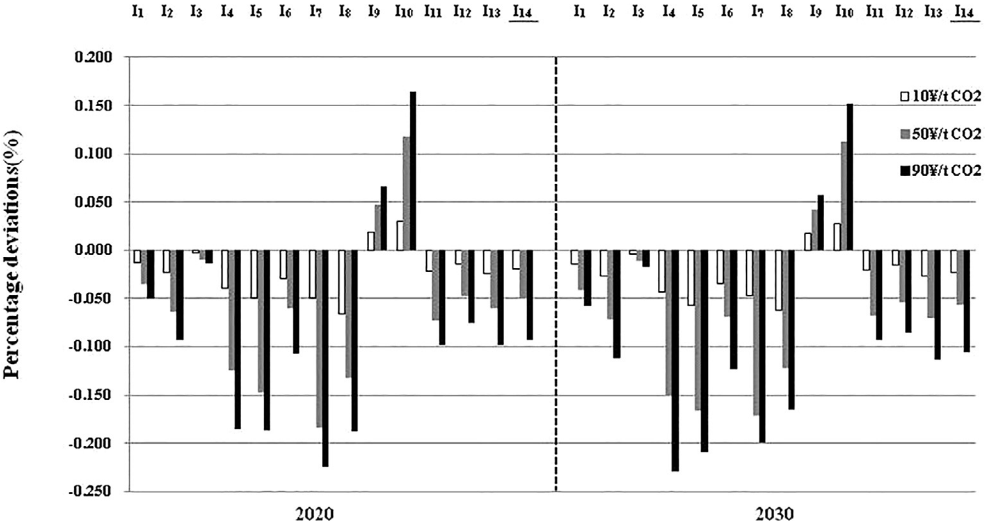

Fig. 3. Changes of carbon intensity in tourism industries.

relative to baseline values under different carbon tax scenarios. This effect of the carbon intensity varies significantly for different tourism industries. As outlined, the most significantly affected tourism industries include those that are involved in the production of alcohol and beverages, the production of other food products, air transport, business services, and accommodation. In general, the higher the tax rate, the more significantly the carbon intensity of tourism-related industries will be affected. Similar percentage deviations are seen in other tourism-related industries. At constant tax rate, the carbon intensity of different tourism industries at different times also leads to different changes. While most tourism industries experience at least a small decline in their carbon intensity (relative to baseline values), some actually experience an increase. Positively affected tourism industries are those involved in the production of transport equipment and business services.

The reducing effect of a carbon tax on CO$_2$ emissions mainly depends on declining energy consumption. Implementing a carbon tax will cause reduced production in all sectors. This phenomenon is particularly apparent in those tourism industries with particularly high CO$_2$ emissions (e.g., those involved in the production of transport equipment). Since these industries always have an extensive mode of development, a reduction of CO$_2$ emissions and the accompanying reduction of added value are not synchronized. The percentage of the latter is higher than that of the former. Thus, the carbon intensity of industries involved in the production of transport equipment will in fact increase in response to a carbon tax scenario.

Yet, the obtained simulation results indicate that the differences between the percentage of the reduction of CO$_2$ emissions and the reduction of value added in the production of transport equipment will increasingly narrow with corresponding increases in the carbon tax rate. Similar to industries involved in the production of transport equipment, the carbon intensity of business services also increases in response to a carbon tax. However, the underlying reasons differ greatly. The business services sector is clearly a non-energy intensive industry, with lower CO$_2$ emissions. Due to the energy substitution effect under a carbon tax scenario, in our simulation, the business services sector begins to use inexpensive energy (such as coal), thus increasing the sector's CO$_2$ emissions. Yet, comparing the increase of CO$_2$ emissions to the increase of value added, the percentage of the former is higher than that of the latter, thus causing a positive change in the level of carbon intensity.

Impacts on the value added by tourism

In the input–output tables of China, the total added value includes the compensation of employees, net taxes on production, depreciation of fixed assets, and operating surplus. Using the recursive dynamic CGE model used in this study, we calculate the impacts of carbon tax on tourism added value, which are reported in Table 6 and Fig. 4. Table 6 provides the impacts of different

Table 6
Impacts of carbon tax on tourism value added.

	Carbon tax (¥/t-CO_2)					
	10		50		90	
Year	2020	2030	2020	2030	2020	2030
Baseline forecast (¥100 million)	80822.40	142342.70	80822.40	142342.70	80822.40	142342.70
Policy simulation (¥100 million)	80714.48	142186.04	80498.87	142033.85	80449.07	141984.30
Deviations (¥100 million)	107.92	156.66	323.53	308.85	373.33	358.40
Deviations (%)	0.134	0.110	0.400	0.217	0.462	0.252

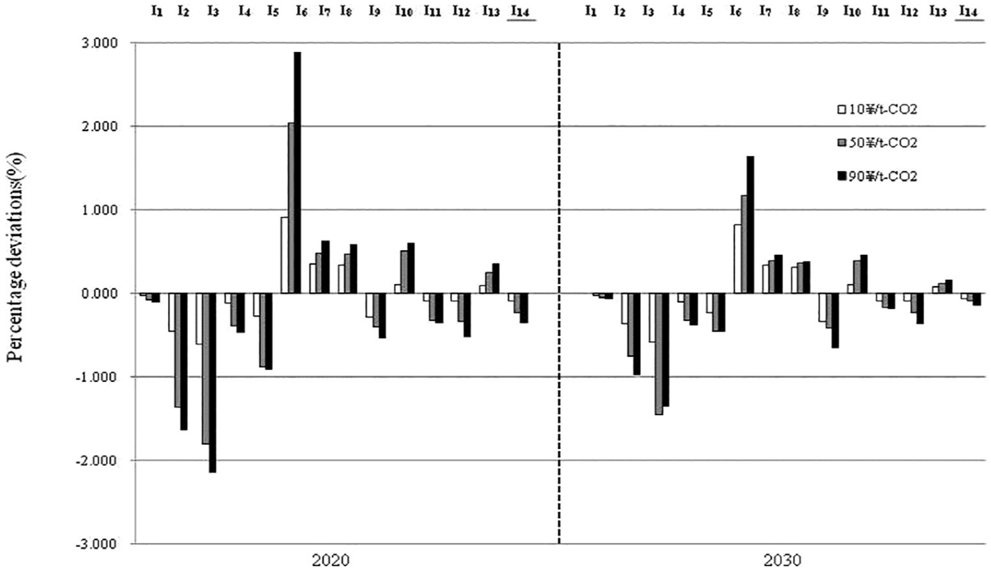

Fig. 4. Changes of value added in tourism industries.

carbon tax rates on Chinese tourism added value by 2020 and 2030. Our results indicate that a carbon tax policy has a significant negative impact on Chinese added value. Particularly, the increased carbon pricing increasingly impacts tourism added value. Furthermore, the impacts of carbon tax decline over time.

Fig. 4 shows the sectoral impacts of the carbon tax in 2020 and 2030 on the tourism sector's added value. Although the impact of a carbon tax on the total tourism added value is negative, the sector-level impacts differ. A carbon tax policy negatively affects some tourism sectors, while positively affecting others. Fig. 4 shows that, in our model, most tourism industries experience some level of contraction to their real added value, relative to baseline values. The most negatively affected would be the water transport sector, while the industry that is affected the least is the transport via railway sector. Business services, culture, art and entertainment activities, and amusement and recreation activities would be positively affected by the levying of a carbon tax. In other words, levying carbon tax increases the added value produced by both sectors. Our results also show that of all tourism-related sectors, amusement and recreation activities would be most affected by a carbon tax policy in terms of added value. In addition, Fig. 4 indicates that higher carbon pricing causes more negative/positive impacts on tourism sectoral added value and these impacts would decline over time.

Impacts on tourism employment

Employment is a further important indicator to assess economic development. We used our recursive dynamic CGE model to simulate the changes of the employment in Chinese tourism by analyzing data for different industries obtained from the China Population & Employment Statistics Yearbook 2012 (NBSPRC, 2013b). Table 7 and Fig. 5 report the obtained results. Levying a carbon tax increases the operating costs of tourism enterprises theoretically, while reducing the demand for employment. Table 7 verifies this statement. In our model, levying a carbon tax poses a significantly negative impact on China's tourism employment. Different carbon tax rates have significantly different effects. Table 7 shows that increased carbon pricing causes stronger impacts, which gradually decrease over time. Chinese tourism-related employment decreases by 0.724% by 2020 when levying a carbon tax of 90 ¥/t-CO_2; the value decreases by 0.110% by 2030 in response to a carbon tax of 10 ¥/t-CO_2, compared to baseline values.

Fig. 5 shows that the food and beverage services sector experiences the most negative impacts with respect to employment in response to implementation of a carbon tax, followed by the accommodation sector. Of all 14 tourism sectors, a carbon tax negatively

Table 7
Impacts of carbon tax on tourism employment.

	Carbon tax (¥/t-CO_2)					
	10		50		90	
Year	2020	2030	2020	2030	2020	2030
Baseline forecast (10 thousand persons)	2027.80	2479.20	2027.80	2479.20	2027.80	2479.20
Policy simulation (10 thousand persons)	2023.36	2476.48	2015.69	2471.43	2013.12	2467.33
Deviations (10 thousand persons)	−4.44	−2.72	−12.11	−7.77	−14.68	−11.87
Deviations (%)	−0.219	−0.110	−0.597	−0.313	−0.724	−0.479

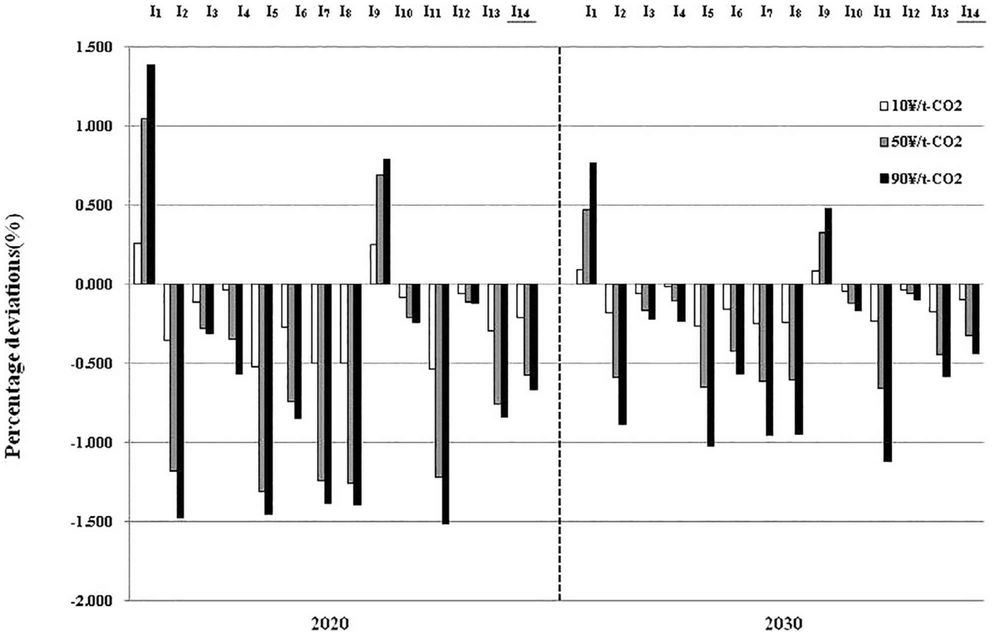

Fig. 5. Changes of employment in tourism industries.

affects 12 sectors, while positively impacting the manufacture of transport equipment and transport via the railway sector. When the carbon price is set at 10 ¥/t-CO_2, 50 ¥/t-CO_2, and 90 ¥/t-CO_2, the simulated values for transport via railway can be expected to increase by 0.261%, 1.044%, and 1.392% in 2020, respectively, and by 0.091%, 0.470%, and 0.766% in 2030, respectively. In all tourism-related sectors, the least affected sector by a carbon tax policy with respect to employment is the sector for management of water, conservancy, environment, and public facilities. Similar to the simulated results for the added value, an increased carbon tax would lead to more negative/positive impacts on tourism sector employment, impacts that decrease over time.

Sensitivity analysis

The simulation results of the CGE model are sensitive with respect to the elasticities of substitutions between capital and energy, and in this case, between different types of energy inputs. Therefore, we conduct a sensitivity analysis depending on different assumptions of these elasticities to evaluate the robustness of our CGE model. We assume that the values of the elasticities of substitution shown in Table 2 form the baseline scenario, while 20% above baseline value provide a high elasticity scenario and 20% below baseline values provide a low elasticity scenario. Table 8 shows the sensitivity tests of our CGE model for a carbon tax rate of 90 ¥/t-CO_2.

The sensitivity tests show that, with increasing elasticity of substitutions, tourism-related CO_2 emissions and carbon intensity are monotonically increasing, employment is monotonously decreasing, and added value remains unaffected. Moreover, all changes with respect to the four variables remain below 2.20%. Therefore, the simulation results are mildly sensitive to the elasticity values in our CGE model. Our CGE model is thus considered robust.

Conclusions and policy implications

This paper uses CGE modeling and conducts a comprehensive simulation analysis of the impacts of a carbon tax on the Chinese tourism industry. Our model uses different carbon tax rates of 10 ¥/t-CO_2, 50 ¥/t-CO_2, and 90 ¥/t-CO_2. The simulation results show

Table 8
Sensitivity tests.

Year	Elasticities of substitution					
	2020			2030		
°C	Scenario 1 low elasticity	Scenario 2 Baseline	Scenario 3 high elasticity	Scenario 1 low elasticity	Scenario 2 Baseline	Scenario 3 high elasticity
CO_2 emissions (Mt)	997.380	1018.774	1041.187	1086.211	1352.691	1379.745
Carbon intensity (t/¥10,000)	0.852	0.867	0.883	0.722	0.734	0.747
Value added (¥100 million)	80449.07	80449.07	80449.07	141984.30	141984.30	141984.30
Employment (10 thousand persons)	2036.271	2013.12	1987.956	2487.562	2467.33	2444.877

that levying a carbon tax can effectively reduce tourism-related CO_2 emissions, particularly those of tourism carbon intensity. Implementing a carbon tax policy can significantly promote the reduction of China’s tourism-related CO_2 emissions. Levying a carbon tax would create significant economic costs for China's tourism industry due to reducing the contribution of tourism to the national economy and impairing tourism employment. In general, higher carbon tax impacts the tourism CO_2 emissions and economy more, while these impacts are decreasing over time. In other words, the impacts of a tax on the tourism are larger in the short term than in the long term. Furthermore, the impacts of a carbon tax vary greatly for different tourism sectors. Our results are of great significance; they aid our understanding of how a carbon tax policy impacts Chinese low-carbon tourism development. As such, our findings can help policy-makers to take informed measures in terms of the implementation of a carbon tax in China. Our analysis specifically highlights three key managerial recommendations that are relevant for Chinese tourism policy-makers:

Regarding tourism enterprises, our results of the CGE model indicate that a carbon tax policy would significantly affect core tourism industries such as air transport, transport via road, and accommodation. To a great extent, the emission reduction targets of these tourism-related industries (also higher CO_2 emissions sectors and core tourism industries) will affect the realization of the CO_2 emission reduction of China's tourism industry. Therefore, tourism industries (particularly for these core industries) should be encouraged to reduce CO_2 emissions by using clean energy and by vigorously introducing, developing, and applying low-carbon technologies. Several concrete countermeasures in transportation and accommodation could effectively reduce CO_2 emissions while simultaneously avoiding the high costs imposed on the tourism industry by a carbon tax. These countermeasures include the development of bio-energy and the use of low-carbon materials in the aviation industry, investment in new energy vehicles for transport via road, popularization of low carbon materials, energy saving and water conservation, and other low-carbon management measures that could be used in the hotel industry. To further popularize low carbon technologies, the Chinese tourism industry should also be required to advocate voluntary CO_2 emissions reductions, thus helping a low-carbon attitude to become part of the tourism enterprise culture.

Regarding the carbon tax price, our results show that the impacts of a carbon tax on different tourism industries would greatly vary under different tax rates and at different times. Thus, when levying a carbon tax, we would also expect the government to implement a comprehensive price strategy. This strategy should consider different prices for different tourism industries at different times, in combination with the further development of China's tourism industry. Furthermore, the levying of different carbon taxes for different tourism industries should be considered. High-energy consumption industries (namely high CO_2 emission industries such as air transport, accommodation, and the production of transport equipment) should be required to pay a higher carbon tax, while low energy consumption industries (namely low CO_2 emission industries such as business services) could pay a lower carbon tax. In such a way, high CO_2 emission enterprises such as transportation and accommodation are (at least to some extent) compelled to accelerate their low-carbon transformation; however, some low CO_2 emission enterprises, such as food and beverage industries, are further encouraged to engage in energy substitution behavior. All these favorable measures will enable a smooth realization of CO_2 emission reduction targets.

Regarding the harmonized carbon tax, the first proposal is the implementation of a carbon tax-compensation policy. Our results show that implementation of a carbon tax policy will negatively influence the economic growth of Chinese tourism, which is a relatively low-margin industry (Wei, Li, & Ren 2016). Therefore, we recommend the provision of a tax compensation for tourism industries. This is particularly necessary for transport and accommodation sectors. These compensations would mitigate the additional costs faced by tourism enterprises based on an implemented carbon tax. The second proposal is to introduce a carbon tax in combination with a revenue recycling-scheme. A redistribution of tax revenue across different departments would create a new influential mechanism for economic development. Recycling the carbon tax revenue in a way that benefits tourism would reduce negative economic impacts on the Chinese tourism industry. Long-term, this would yield a double dividend: tourism economic growth and CO_2 emissions reduction. Additionally, the carbon tax revenue could also be used to encourage different tourism sectors to seek out and use cleaner and more sustainable forms of energy to reduce their CO_2 emissions.

It is worth noting that there are some limitations to this study. Our CGE model is a single country model; therefore, all other countries and regions are studied as an economic subject in the trade module. In addition, no official data on greenhouse gas emissions in China is currently available. Instead, the model is based on estimated greenhouse gas data via analyzing the China Energy Statistical Yearbooks of 2012 and 2013. The process of this study indicates some potential avenues as priorities for future work. Considering the importance of corporate carbon tax rates for the implementation of a low-carbon strategy, future work could focus on a carbon tax policy with a compensation plan or on carbon tax revenue recycling schemes. Carbon taxation not only reduces the industry's CO_2 emissions while increasing the industry's operating costs, but it may also affect their operative behavior. Therefore, the state of mind of tourism stakeholders of carbon taxes requires further research. Additionally, a comprehensive framework of a reduction of the CO_2 emissions of China's tourism industry should be developed. We should discuss the relevant political and economic factors regarding a reduction of Chinese tourism-related CO_2 emissions and economic growth in a more comprehensive framework.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China under Grant (71764027) and Nanhu Scholars Program for Young Scholars of Xinyang Normal University.

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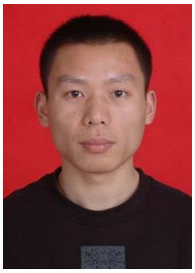

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