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Decompose Tourism Greenhouse Gas Emission Using the Environmentally Extended Input-Output Framework: An Example of Taiwan

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ABSTRACT

Growth of global tourism volume contributes to the greenhouse gas emissions while improvement of technology efficiency suppresses this trend. The purpose of this research is to decompose the tourism carbon emission for island destination, Taiwan, to assess the dynamics of these two factors using the Environmentally Extended Input-Output Model. Between 2001 and 2011, Taiwan tourism consumption increased by 49% but total carbon footprint, including direct effect, domestic indirect effect, and embedded carbon through imports, grew 17%. The technology improvement is about three-fourths of the speed of the current tourism demand expansion, thus cannot wholly compensate the GHG emissions produced by final demand changes. In addition, the tourism carbon intensity, measured by emissions per dollar GDP, is stagnated while the national average of the same ratio improves by 20% within the same period. Considering tourism demand continues to grow, proactive actions such as carbon tax, aviation tax or carbon offset programs is called for to curtail future tourism carbon footprint.

KEYWRDS: Tourism carbon footprint; Decomposition analysis: Environmental Extended Input-Output Model

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1. Introduction

A two-way relationship between tourism development and climate change is recognized and documented in many perspectives. On one hand, tourism consumption leads to energy use and greenhouse gas (GHG) emissions, contributing to the acceleration of climate change. In return, climate change results in shifting of tourism demand regionally and globally, degradation of environmental quality at destinations, increasing burden of mobility cost, and social unrest during severe weather patterns (WTO-UNEP, 2008).

The foundation to effectively manage the tourism development and climate change relationship is partially based on credible evaluation of the magnitude of anthropogenic activities and carbon emissions. In 2008, the World Tourism Organization (WTO) and United Nationals Environment Programme (UNEP) published the first seminal and comprehensive evaluation of tourism contribution to the global GHG emissions. It is estimated that worldwide tourism activities in 2005 contributed 1,302 million tons (Mt) of GHG, around 4.9% of global CO_2 emission. Besides providing a baseline portray, an important endeavor is invested to project the possible scenarios of tourism GHG in the next 20 years. Based on a forecast of a 4% annual growth rate of international tourist arrivals, the tourism emission will experience 161% growth and reaches 3,000 Mt in 2035.

This business-as-usual scenario in 2035 although worrisome have ways to be mitigated (WTO-UNEP, 2008). One approach is through the enhancement of technical efficiency by adoption of energy saving equipment such as fuel-efficiency aircraft as well as the adoption of renewable energy sources in the production. If maximum assumed technical efficiencies were achieved, the tourism emissions in transportation, accommodation, and recreational activities can be reduced by 38% from the business-as-usual baseline. The second approach, the travel modal shifting, involves tourists' behavior changes, such as transportation modal shifts, preferences for shorter-haul destinations, and increasing length of stay, which accordingly will lead to a reduction of 44% of tourism carbons. In combination of both mitigation strategies, the tourism emissions in 2035 is expected to be at least 20% lower than the baseline point in 2005.

After the initial WTO-UNEP report, evaluation of tourism carbon footprint (CF) received prominent academic attention. Empirical cases include nationwide evaluation (Dwyer, Forsyth, Spurr, & Hoque, 2010; Sun, 2014) and regional assessment (Hanandeh, 2013; Konan & Chan, 2010; Whittlesea & Owen, 2012). However the current literature generally presents a snapshot of the relationship, typically for a one-year time period. Consecutive evaluation of tourism emissions based on a consistent framework is rarely available, with the only exception of the Dutch holidaymakers carbon footprint study from 2002 to 2012 (de Bruijn, Dirven, Eijgelaar, & Peeters, 2013). The lack of time-series data leads to several empirical questions unanswered. First, will total tourism emissions increase in a direct proportional to tourism consumption over time? This fundamental question originates from the possibility that the efficiency improvement of energy consumption is insufficient to counter global travel demand. Especially, international tourism volume frequently surpasses the projected growth rate of 3.8% proposed by UNWTO, representing a strong and sustained demand pattern into the future (UNWTO, 2014). Another needed answer is the eco-efficiency comparison of the tourism industry in relative to other sectors. This information frames the urgency of mitigating tourism carbon emissions under the national GHG reduction targets. The assessment of above-mentioned questions requires the comprehensive and longitudinal tourism carbon footprint figures, which help to reveal the dynamic of tourism demand (in quantity and consumption value) and carbon emissions (Sun, 2014).

The purpose of this study is first to compare the GHG emission for island destination Taiwan over a decade using the Environmentally Extended Input-Output Model (EEIO). The scope addresses all emissions associated with tourism consumption by eight categories within the national territory for its direct and indirect economic transactions. Secondly, carbon emissions is decomposed by factors to trace the dynamics between economic, structural and technological changes during 2001 and 2011 as a vehicle to understand the progress of technology improvement in energy consumption versus final demand changes. Last, the eco-efficiency of tourism against others sectors is established to highlight our current status given a high priority in tourism development.

2. Method

The analytical framework of this research is presented in Figure 1. The first step is to determine the scope of tourism consumption covered in the evaluation. The UNWTO assessment of global tourism emission only comprise of transportation, accommodation and recreational activities while left out consumption associated with food, shopping, travel service or entertainments (WTO-UNEP, 2008). Their approach simplifies the data requirement but can only provide a conservative figure of reality. In this research, the scope is based on a framework proposed by Sun (2014), which stated that a comprehensive tourism carbon evaluation shall be in line with the tourism consumption reported in Tourism Satellite

Account (TSA). All production activities associated with domestic tourism consumption, inbound tourism consumption and domestic spending associated with outbound travel (e.g., domestic transportation and purchases of travel related items) have to be included. This consumption comprises of accommodation, food & beverage, transportation (air, land, car-rental), entertainment, travel-agent service, and shopping. International aviation, for which the carbon emissions released by national carries for a share contributed by both inbound and outbound tourists, is also included.

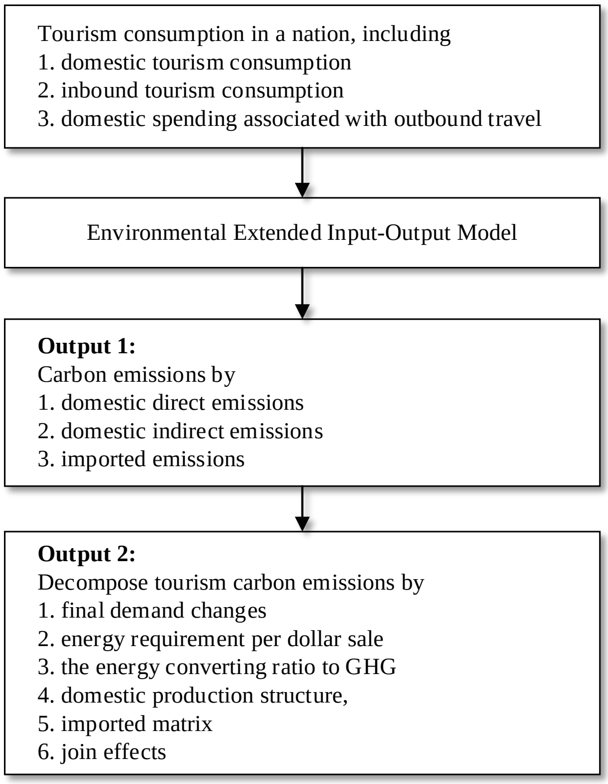


Figure 1. The analytical framework

The spending figure is then feed into the Environmental Extended Input-Output Model (EEIO) to calibrate the resulting GHG emission for the production of tourism products and services. EEIO is credited for its transparency to compute the economy-wide impacts on resources required and waste produced, and its ability to trace movement through cross-broader activity for imports and exports (Wiedmann, 2009; Wiedmann, Minx, Barrett, & Wackernagel, 2006). EEIO produces three types of output: domestic direct emission, which refers to the emissions directly associated with industries serving tourists (such as hotels and transportation); domestic indirect carbon emissions for activities occurred through the supply chains; and embedded emissions through imports. For the first two sources, the direct and indirect domestic requirement of energy and the associated GHG emissions given one dollar change in final demand are calculated as follows (Miller & Blair, 2009):

$$\text{GHG emission} = EPX = EP\,(I\text{-}Ad)^{-1}Y$$

Where X represents the amount of total domestic production (n x1);
$(I\text{-}Ad)^{-1}$ is the Leontief inverse matrix (n x n);
Y is the final demand change (n x1);
E is the industry energy coefficient vector (n x1), which is the total amount of energy consumption divided by total domestic production;
P is the industrial GHG emission factor (n x1), equal to the total GHG emission divided by total energy consumption

The general approach to account for the carbon emissions related to imports is to trace the production function using the global inter-national input-output models or the multi-regional input-output model (Wiedmann, 2009; Wiedmann, Lenzen, Turner, & Barrett, 2007). A detailed calculation formula for multi-regional IO analysis can be found at Peters (2008). If such an inter-country transaction table is not available, an approximation can be thought of by using the "domestic technology assumption (DTA)," which assumes that imported goods are produced under the same technology procedures as domestic goods[3] (Druckman, Bradley, Papathanasopoulou, & Jackson, 2008; Wood & Dey, 2009). The computation of the embedded carbon footprint of imports is as follows:

$$\text{GHG for imports} = EP\,(I - A_d)^{-1}A_m(1 - A_d)^{-1}Y_d + EP\,(I - A_d)^{-1}Y_m,$$

Where
Y_d = Visitor consumption of domestic products
Y_m = Visitor consumption of imported goods
A_m = Imports technical input coefficients

For the decomposition analysis, we adopt the analytical framework proposed by Chang, Lewis, & Lin (2008). The EEIO structure decomposition analysis breaks down total

[3] The other argument for adopting the DTA assumption is that the evaluated county has no jurisdiction over foreign products. Adopting the DTA provides an assessment for demonstrating the scale of emissions produced if these imported products are produced domestically (Turner, Munday, McIntyre, & Jensen, 2011).

CO2 emission into six components: 1) the energy converting ratio with respect to GHG emission, 2) energy requirement per dollar of final demand, 3) domestic production input-output table, 4) final demand changes, 5) imported matrix input-output table, and 6) join effects. Final demand changes represent the magnitude of anthropogenic activities in respond to the need of recreation and travel. Factor 2 and 3 portray the technology status in energy use while factor 4 and 5 represent the economic structure for inter-industry linkage.

$$\Delta GHG = E_t P_t (I-Ad_t)^{-1} Y_t \; - \; E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} Y_{t-1}$$

$$= E_t P_{t-1} (I-Ad_{t-1})^{-1} Y_{t-1} \; - \; E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} Y_{t-1} \qquad \text{(Factor 1)}$$

$$+ E_{t-1} P_t (I-Ad_{t-1})^{-1} Y_{t-1} \; - \; E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} Y_{t-1} \qquad \text{(Factor 2)}$$

$$+ E_{t-1} P_{t-1} (I-Ad_t)^{-1} Y_{t-1} \; - \; E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} Y_{t-1} \qquad \text{(Factor 3)}$$

$$+ E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} Y_t \; - \; E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} Y_{t-1} \qquad \text{(Factor 4)}$$

$$+ E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} A_{mt} (1 - Ad_{t-1})^{-1} Y_{t-1} - E_{t-1} P_{t-1} (I-Ad_{t-1})^{-1} A_{mt-1} (1 - Ad_{t-1})^{-1} Y_{t-1} \qquad \text{(Factor 5)}$$

$$+ \text{joint effects} \qquad \text{(Factor 6)}$$

Data sources

The time series data we will explore range from year 2001 to 2011. The length of time incorporated in this study is in part determined by the availability of IO table, tourism satellite account and the energy data, but also reflects a stage where Taiwan tourism experiences a substantial growth for which an annual growth rate of 9% for inbound tourism was recorded. The required data in compiling an EEIO model was Taiwan IO tables for domestic transaction table and import matrix (Directorate-General of Budget Accounting and Statistics, 2009); energy balance sheet for energy consumption data by 38 industries with 40 energy types from 1982 to 2012 (Bureau of Energy, 2013a); energy and CO_2 conversation factor between 12 energy types, electricity consumption, and carbon-dioxide from the IPCC 5.0 and 6.0 version (Bureau of Energy, 2013b). The 2011 IO table was not available at the time of this research so that an IO table updating technique suggested by Eurostat was adopted (EUROSTAT, 2008). Visitor consumption information was obtained from Taiwan Tourism Satellite Account and was broken by detailed spending profiles (Taiwan Tourism Bureau, 2001-2013, 2007).

3. Results

Taiwan tourism carbon footprint for 2001 and 2011

Based on Taiwan Tourism Satellite Account, the total tourism injection in 2001 and 2011, including inbound tourism expenditure, domestic tourism expenditure, and domestic spending associated with outbound travel was NT$500.9 billion and NT745.2 billion (+49%) by the 2001 prices. With such strong demand on services, Taiwan tourism carbon footprint increased from 12.58 Mt in year 2001 to 14.68 Mt in 2011 (+17%) (Figure 2). Domestic direct CO_2 emission, emitted by the industries directly serving tourists, increased by 24% while the indirect CO_2 emission increased by 20%. Carbon embedded through imported products decrease by 20% as a sign for economic structure changes. This implies the Taiwan production structure has less integration with the global supply chains on items and services serving tourists, and moves toward more domestic interdependences so that intensive domestic linkages and transaction are created, especially on food and shopping items.

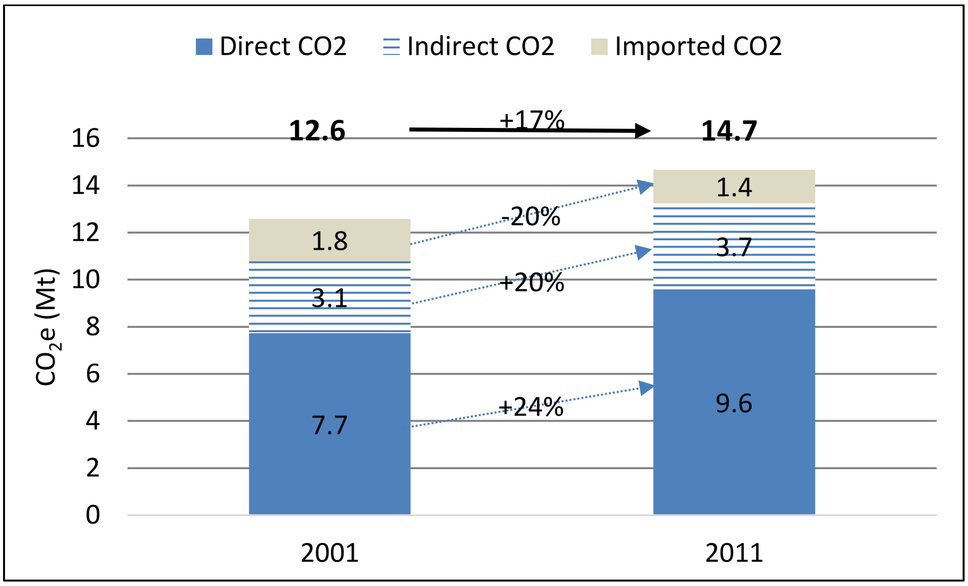
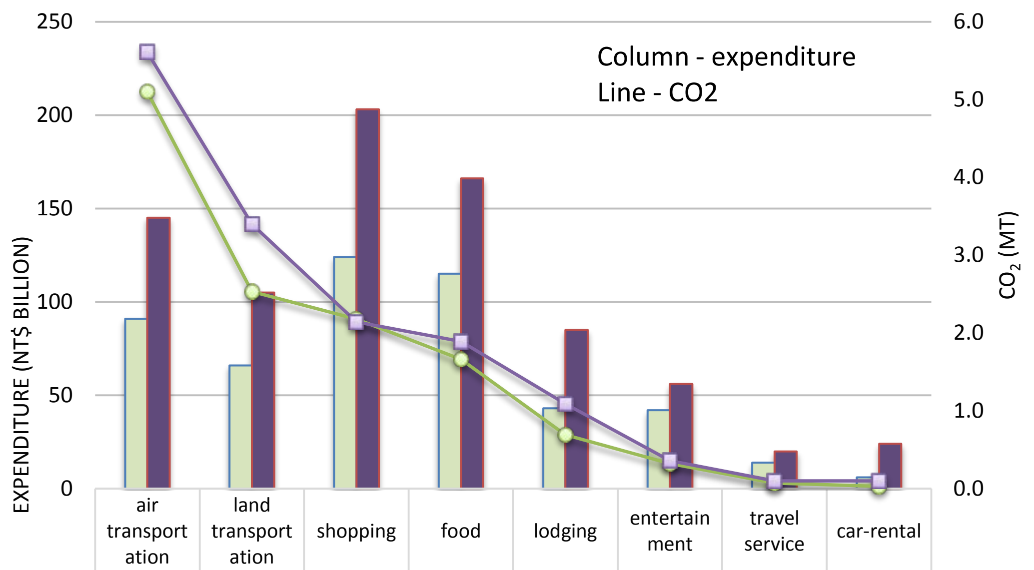


Figure 2 The Taiwan tourism carbon footprint in 2001 and 2011

Figure 3 demonstrates the sector-specific pattern for visitor consumption and carbon footprint. The column represents the amount of consumption on each sector while the line with markers indicate the magnitude of carbon emissions. The figure indicates that each sector reported at least 30% growth rate in sales, but only experienced modest carbon emission increase during the 10-year period. The improvement of technology efficiency is found to be much faster among manufacturing than service sectors based on the indicator of per dollar carbon emissions. This subsequently leads to a lower carbon impact for purchases made related to tangible products, such as souvenir consumption. The technology improvement in the shopping related sectors is found to fully compensate the additional energy consumption results from the increased volume in production. In terms of the critical component, air and land transportation are responsible for the majority (>60%) of the tourism carbon emission for this island destination, and their energy intensity ratio per dollar is highest. Although per dollar energy intensity has improved by 30% and 8% for air and land transportation, respectively, these two sectors still reported the largest net increase of carbon emissions among all tourism-related business.



	air transportation	land transportation	shopping	food	lodging	entertainment	travel service	car-rental
2001 spending	91	66	124	115	43	42	14	6
2011 spending	145	105	203	166	85	56	20	24
2001 CO2	5.1	2.5	2.2	1.7	0.7	0.3	0.1	0.0
2011 CO2	5.6	3.4	2.1	1.9	1.1	0.4	0.1	0.1

Figure 3 Tourism consumption and carbon emissions in 2001 and 2011

Decomposition Analysis

To understand the underlying factors that contribute to the CO_2 emissions over a ten-year period. We decomposed the differences of GHG into six individual component:

1) the energy converting ratio with respect to GHG emission, 2) energy requirement per dollar of final demand, 3) domestic production input-output table, 4) final demand changes, 5) imported matrix input-output table, and 6) join effects.

The 2011 tourism carbon footprint increases 17% from the 2001 year baseline. The increase is contributed mainly by final demand expansion (64%), and stronger inter-industry linkages (12%). At the same time, the GHG emission is offset by the improvement in the energy combustion efficiency (-1%, meaning this factor reduces the year 2011 CO_2 emission by 1% from the baseline point), decreased energy use per dollar output (measured by kilocalorie) (-28%), fewer demand on imported materials (-4%) and joint effect (-27%) (Table 1).

Table 1 Decompose CO_2e emission into six factors

	CO_2e (Mt)	Pct = factor CO_2e / 2001 tourism CO_2e
$\Delta GHG = CO2_{2011} - CO2_{2001}$	2.10	17%
= Factor 4 : final demand	8.10	64%
+ Factor 3 : domestic production structure	1.53	12%
+ Factor 5 : imported production structure	-0.14	-1%
+ Factor 1 : the energy converting ratio to GHG emission	-0.47	-4%
+ Factor 2 : energy requirement per dollar of final demand	-3.54	-28%
+ Factor 6 : join effects	-3.38	-27%

This result supports two general observations. First, overall tourist consumption is the major driver in pushing up the tourism GHG emissions, especially under the Taiwan governmental objectives for swift expansion in total tourist numbers. In addition to it, the diversification of domestic economic structure for products and services consumed by tourists facilities the domestic inter-industry transaction and the associated energy consumption through supply chains for every dollar output in tourism. This, at the same time, drives down the demand for imported products and the embedded carbons. However, the magnitude of these two factors is quite negligible. Secondly, the Taiwan production industry exhibits technology improvement pattern over time for their efforts on reducing reliance on fossil energy, adopting solar thermal and biomass, and increasing the combustion efficiency of energy. Figure 3 demonstrates that if the 2011 consumption was supported by the production structures dated back to year 2001, the projected total emission would reach 21.73 Mt, equal to a 73% increase from the baseline. The technology improvement and its join effects of Taiwan's industry holds back 56% of the originally needed energy and the associated emissions. The net increase of carbon footprint thus is 17% from the baseline. From a holistic perspective, the technology improvement is about three-fourths of the speed of the current tourism demand expansion, thus cannot wholly compensate the GHG emissions produced by final demand changes.

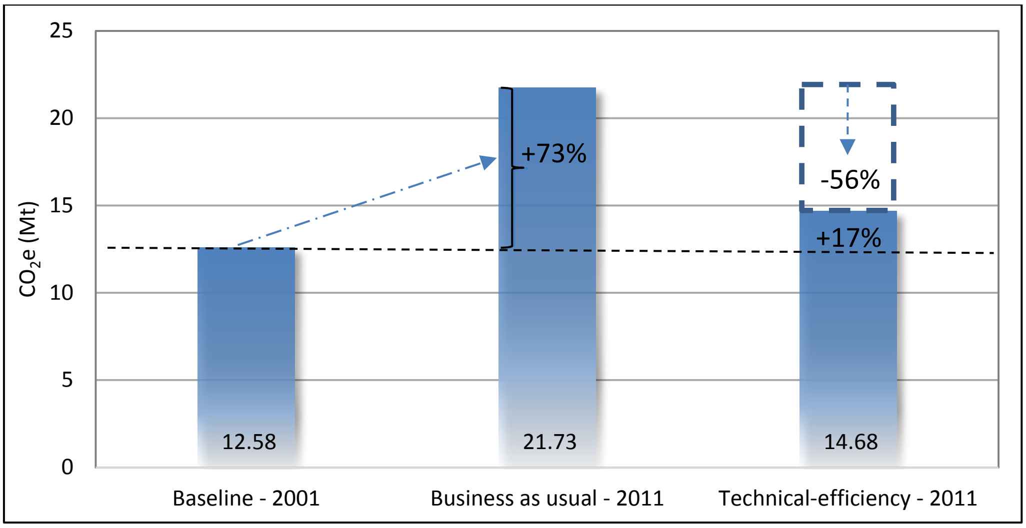


Figure 3 Tourism carbon footprint by year and by scenarios

Carbon intensity

The last part of the analysis addresses the carbon intensity of the tourism industry against the national averages, measured as the CO_2 emission per dollar of GDP. The Taiwan national average carbon intensity is 0.027 kg/dollar of GDP in 2001 and decreases to 0.017 kg/dollar of GDP in 2011 (-23%) (Table 3). On the contrary, the tourism carbon intensity, around twice of the national averages, remains very stable over the decade, around 0.045 kg/ dollar of GDP. In other words, the carbon intensity of the tourism does not improve in a direct proportional as the national average. Two possible reasons for this pattern as first, a lower percentage of tourism expenditure is converted to GDP in terms of profit, personal income, or tax over the decade. For example, one dollar injection in the air transportation sector in 2001 would yield 0.33 dollar in value added, but the ratio drops to 0.21 dollar in 2011 (-36%). Secondly, the Taiwan tourism industry does not progress as fast as other sectors in technology improvement for energy consumption. The combination of both factors lead to a stagnated carbon intensity ratio for the tourism consumption in Taiwan.

Table 2 The GDP and carbon intensity of all production and tourism consumption, respectively

Year	Taiwan GDP (NT$ billion)[1]	Taiwan CO_2 emission (Mt)[1]	National CO_2/GDP (kg/NT dollar)[1]	Tourism GDP (NT$ billion)[2]	Tourism CO_2 (Mt)	Tourism CO_2/GDP (kg/NT dollar)
2001	9,862	213	0.022	271	12.58	0.046
2011	13,841	254	0.017	324	14.68	0.045
Pct change	40%	19%	-23%	20%	17%	-3%

[1] (Bureau of Energy, 2013c)
[2] (Taiwan Tourism Bureau, 2007)

4. Conclusion

Importance of this study can be elaborated from the following perspectives. First, for Taiwan an island destination, although energy emission intensity and the energy use structure were improving substantially over the past decade, this factor solely cannot compensate the carbon emissions produced from the expansion of tourism, 9% annual growth rate in inbound tourism and 5% in domestic tourism between 2001 and 2011. The modal shift strategy for shorter-haul destinations and changes of transportation vehicle is especially challenging at island destinations as international aviation cannot not be easily displaced and will maintain its major contributor role to the overall tourism carbon footprint.

The tourism carbon efficiency has been documented to be worse than the national average in carbon emissions per dollar output (Becken & Patterson, 2006; Dwyer et al., 2010; Sun, 2014). In this study, we further demonstrates tourist carbon emissions per dollar GDP is stagnated while the national average of the same ratio keeps improving over time. In other words, one dollar spent on the tourism related products and service will generate a smaller contribution to the national GDP while lead to a larger amount of GHG then spending this dollar on other industry in average. From a national perspective, this presents a dilemma to achieve the carbon mitigation targets when receiving a large and fast-expanding volume of international arrivals and domestic tourists. Because technology improvement in the production process cannot single-handed offset the GHG emissions from the rising tourism demand, it is necessary for governments to impose proactive actions – such as carbon tax, aviation tax or carbon offset programs, to curtail future tourism carbon footprint.

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