Sustainable tourism modelling: pricing decisions and evolutionarily stable strategies for competitive tour operators

He, Yong, He, Peng, Xu, Faye and Shi, Victor (2018) Sustainable tourism modelling: pricing decisions and evolutionarily stable strategies for competitive tour operators. Tourism Economics, 25 (5). pp. 779-799. ISSN 1354-8166

http://dx.doi.org/10.1177/1354816618806729

This is the Accepted Version of the final output.

Sustainable tourism modelling: Pricing decisions and evolutionary stable strategies for competitive tour operators

Abstract

This paper considers competitive tour operators (TOs) who may select traditional tourism strategy (strategy T) or green tourism innovation strategy (strategy G) and addresses the following important issues using evolutionary game models: When would TOs facing environment-friendly tourists adopt the strategy G? How do TOs set product prices under different strategy combinations? How can government effectively motivate TOs to pursue green tourism? Our research results show that a green tourism innovation pioneer could monopolize the market under certain conditions. Furthermore, when environmental preference of tourists is sufficiently low, no TOs would adopt the strategy G; when it is moderate, only the TO with cost advantage (stronger TO) would adopt the strategy G; when it is sufficiently high, both TOs would select the strategy G. Our research also demonstrates that the stronger TO implements the strategy G mostly independent of the rival's decisions, but the opposite is true for the TO with cost disadvantage (weaker TO). We further investigate potential government subsidies that can motivate TOs to carry out green tourism simultaneously. Our results suggest that to be more effective, the government should first offer green subsidy to highly competitive tourism locations and/or more innovative TOs.

Keywords: Green tourism innovation; Pricing; Hotelling model; Evolutionary game theory; Government subsidy

Introduction

Tourism has become an important part in many countries around the world. China is no exception to this trend. China has witnessed fast growth with an average growth rate 12% in tourism income and about 10% of the total consumption of Chinese was on tourism related products in 2015 (Liu et al., 2017). As one of the driving forces of China's service industry, tourism industry plays a significant role in promoting economic growth. However, many scholars have argued that economic growth and industrial development in developing countries mainly rely on excessive resource consumption, leading to low energy efficiency and high emissions (Adriana, 2009; Carrillo et al., 2014). In particular, tourism industry consumes a lot of natural resources, and brings about a large number of disposable products, resulting in severe contamination of air, oceans, soil, fresh-water and so on (Chu and Chung, 2016; Fong et al., 2017; Han and Yoon, 2015). In order to achieve sustainable development, we should carefully consider the potential negative impacts of tourism consumption on the environment. For instance, the problems of haze pollution, global warming, ozone depletion, and greenhouse effect are particularly serious in China (Hou et al., 2017). Fortunately, as people have become more environmentally conscious, many countries around the world, including China, have advocated green tourism focusing on eco-friendly tourism service products. As an example, the Chinese government has been advocating "low carbon tourism" when developing the tourism industry into a strategic pillar industry of the national economy[1].

In realities, product strategy plays a critical role in the survival and success of a firm because it can determine the firm's orientation of the business activities and expand its market share. Enterprises often adopt strategies such as low price and/or product differentiation strategy to capture more market shares (Agrawal and Bellos, 2016; Zhu and He, 2016). With the continuous improvement of people's living standards, consumers have growing interests

[1]State Council. (2009). The suggestions of promoting tourism industry. Issued by State Council, No.41.

on tourism nowadays (Chan et al., 2014). Meanwhile, thanks to some governments' great efforts on environmental protection, people also increasingly prefer green products and services. Many researchers have pointed out that consumers would like to pay extra for green products and services (Abdallah et al., 2012; Zhu et al., 2007; Zhang et al., 2017). As a consequence, successful firms often require their managers to consider not only the quality of products and services but also other aspects such as consumers' environmental preference (Buckley, 2012). Research and Development (R&D) of environmental products is one of the important issues of sustainable operations (Lee and Min, 2015). So far, many industries have adopted green product strategy to meet and exceed the social environmental standards (Loiseau et al., 2016). Nevertheless, tourism firms offering green service products face higher cost in green innovation and/or waste disposal. Therefore, a tour operator (TO) has to make a trade-off between profit and the cost of being green and decide whether to implement green tourism innovation according to the market. Different from physical products, the tourism service products are produced while being used by tourists. As Vargo and Lusch (2008) argued, consumers are not only the buyers of the services, but also the co-producers or co-creators of service value. Thus, the additional green tourism cost is often related to the demand volume (such as unit carbon emission reduction), which differs from the situation for the green physical product innovation (Wong, 2013).

In practice, decision-making is oftentimes not one-shot and decision makers are not completely rational. They would constantly adjust their strategies after observing competitors' actions and finally select a stable strategy. This is the core idea of Evolutionary Game Theory (Weibull, 1997). This tool is highly applicable to our research as the tourism industry is constantly evolving with tourists' increasing environmental awareness. Therefore, we will construct evolutionary game models to analyze the dynamic system's Evolutionary Stable Strategy (ESS), which, if adopted by a population in a given setting, cannot be invaded by any alternative strategy (Smith and Price, 1973). Considering the characteristics of tourism service products, we will study the strategic interaction of TOs' green tourism innovation and aim to answer the following important questions:

(1) Under what conditions would TOs adopt the strategy G? And what are the optimal product prices for TOs in different competitive settings?

(2) How do the environmental preference of tourists and initial states of TOs adopting the strategy G influence the ESS of TOs?

(3) Under what circumstance can the government subsidy effectively motivate the TOs to implement green tourism? And how does the government green subsidy affect the ESS of TOs?

To address the above-mentioned questions, we first derive the demand functions based on the classical Hotelling model where we also incorporate the environmental preference into tourists' utility function. We then establish a one-shot duopoly game model and two evolutionary game models consisting of two asymmetrical TOs. By analyzing these models, we obtain the optimal prices, demands and profits of TOs and identify the evolutionary stable conditions. Furthermore, we propose possible government subsidies that can effectively motivate TOs to implement green tourism innovation. Our analysis and results show that the weaker TO may adopt the strategy G when the environmental preference of tourists is moderate or high, but it is significantly affected by the stronger TO's decisions. The stronger TO makes product decisions mainly depending on his profit and rarely considering his rival's decisions. We further conclude that when the environmental preference of tourists is sufficiently low, both TOs will adopt the strategy T; when it is moderate, only the stronger TO will adopt the strategy G; both will adopt the strategy G when it is very high. Our findings also suggest that the government start by selecting highly competitive tourism locations and/or more innovative TOs to implement green subsidy policy.

The rest of the paper is organized as follows. In the next section, we review the representative studies closely related to our research. We then describe the research problem and derive the demand functions in the third section. Section 'One-shot duopoly game among TOs' characterizes the one-shot duopoly game of TOs. In section 'Evolutionary analysis of TOs', the ESSs of TOs are explored. Section 'ESS of TOs with government subsidy' examines the effect of government subsidy on the ESS of TOs. We conclude the paper in the last section where we also present some avenues for future research.

Literature review

In this section, we will review the representative literature from three research areas: green innovation strategy, sustainable tourism and pricing in tourism industry.

Green innovation strategy

Many researchers have studied green innovation management (see Agrawal and Bellos, 2016; Blanco et al., 2009). They confirm that it is difficult for enterprises to pursue green innovation activities when consumers have lower environmental awareness. Hansen and Birkinshaw (2007) indicate that innovation value differs from firm to firm and suggest that firms decide on innovation according to their own specific situations. Ghosh and Shah (2012) establish game-theoretic models to investigate the effect of channel structures on product greenness, prices and profits considering green production cost and consumer sensitivity on green apparel. They propose a two-part tariff contract to coordinate the green channel. Carrillo et al. (2014) develop a dual channel model to analyze the influence of customer environmental sensitivity on its supply channels. They suggest that policy makers consider the disparate effect on different industries for carbon tax schemes. Dai and Zhang (2017) investigate the green process innovation and dynamic pricing setting under carbon tariff and emission cap. They find that carbon tariff could reduce product innovation, domestic price, profit and social welfare, but could increase foreign price. Some researchers have shown that government regulations could effectively motivate firms to carry out green innovation from a short-term perspective (e.g., Droste et al., 2016; Kammerer, 2009; Qi et al., 2010; Wang et al., 2017). For example, Droste et al. (2016) explore the institutional conditions that promote the transition towards sustainability under government intervention. They point out that government intervention could facilitate social innovation towards sustainability. Wang et al. (2017) examine the effects of insurance subsidy on clean production innovation. They demonstrate that green insurance can't improve product innovation and profit, but can reduce risk. Additionally, some studies (Osloob and Foumani, 2017; Kuchukova et al., 2016) consider the innovation performance of firms and their roles in the markets. In short, the above-mentioned papers show that green operations of an enterprise could improve its core-competitiveness and contribute to sustainability. Nevertheless, the majority of the previous studies focus on the optimal prices and green levels assuming participants are perfectly rational. Furthermore, all of them are unrelated to the choice of green tourism innovation strategy.

Sustainable tourism

Many scholars (e.g., Chen and Tung, 2014; Dunk et al., 2016; Suriñach and Wöber, 2017) have paid more attention to sustainable tourism management and point out that tourism industry brings about a lot of disposable products, which can lead to soil and water pollution. Also, some studies (De Vita et al., 2015; Katircioglu et al., 2014) focus on the links between tourism development and environmental quality. Adriana (2009) investigates the environmental protection issues in tourism supply chains. Their findings indicate that public pressures can promote the adoption of green supply chains but organizational factors and strategic myopia of players can hinder the implementation of sustainable tourism. Chan et al. (2014) collect data through a survey from 438 hotel employees in Hong Kong and examine the effects of three green triggers: environmental knowledge, environmental awareness and environmental concern. They demonstrate that these three triggers are positively associated with the ecological behavior of tourists. Xu and Fox (2014) note that any movement towards sustainable tourism needs to consider all key stakeholders in the process. Integrating several essential variables (environmental awareness, perceived effectiveness, and eco-friendly behavior) into tourists' environmental preference, Han and Yoon (2015) find that the incorporated construct plays a vital role in hotel guests' decisions. Rahman and Reynolds (2016) establish a comprehensive model of consumers' behavioral decisions and examine the interaction among consumers' biospheric value, their willingness to sacrifice for environment, and their behavioral intentions. They conclude that biospheric value would influence consumers' willingness to sacrifice for the environment. Wang et al. (2017) assess the recreation carrying capacity of the environment attributes considering the willingness to pay of tourists for environmental products and identify the carrying capacity threshold for each specific attribute. He et al. (2018) set up a dynamic evolutionary game model among local governments, tourism enterprises and tourists. They then develop an effective green incentive mechanism for government to develop traditional tourism into green tourism. The majority of these previously mentioned papers mainly investigate the relationship between tourists and sustainable development. However, as a key stakeholder of sustainable tourism, TOs' pricing and/or product strategies will significantly influence tourists' purchasing decisions when choosing tourism service products (Huang et al., 2010; Lee and Min, 2015). This is a feature specifically incorporated in our research.

Pricing in tourism industry

Some research papers have analyzed the pricing decisions in the tourism service industry (e.g., Guo and He, 2012; Song et al., 2009; Taylor, 1998; Zheng, 1997). Chung (2000) modifies a prisoner's dilemma game model to examine the pricing strategy and business performance of hotels and obtain the pricing policies in different situations. Lockyer (2005) investigates the perceived importance of price when selecting hotel accommodation and identifies the price trigger points that would influence the purchasing behavior of tourists. García and Tugores (2006) construct a vertical differentiation duopoly model considering both quality and price competition in the hotel industry. They derive the optimal quality and price decisions. Huang et al. (2010) study the pricing strategies in competitive tourism supply chain and point out the rational reactions of each sector under different strategies. Abrate et al. (2012) study the dynamic pricing strategy for hotels and show that the type of customer, the star rating and the number of suppliers with available rooms can affect the pricing structure. Guo et al. (2013) explore the optimal pricing strategy for hotels when managers operate an online channel by cooperating with a third party website and propose a coordination mechanism for the stakeholders to achieve a win-win outcome. Dong et al. (2014) study the pricing and cooperative strategies between tour operators and hotels located at a tourism destination. They find that the tour operators would bid a lower wholesale room price to the hotel with higher capacity and vice versa. Yang et al. (2016) discuss a two-echelon tourism supply chain consisting of a hotel and an online travel agency by comparing sequential game with price competition. Long and Shi (2017) investigate the optimal pricing strategies of a tour operator and an online travel agency when they adopt the O2O model through online sale and offline service cooperation. They find that service level, unit sale commission, cost coefficient and unit service compensation coefficient have different influences on pricing decisions of the tour operator and online travel agency. Most of these papers mainly study price competition among tourism participants. Our research differs by focusing on the strategic choices of green tourism innovation and pricing policies simultaneously in sustainable tourism.

Furthermore, differently from the existent literature, our study incorporates the environmental preference of tourists into the horizontal competition model under bounded rationality assumption. We analyze the pricing decisions and the strategic interaction of TOs' green tourism innovation. Moreover, we aim to find out when government subsidy policy can promote green tourism. To our best knowledge, these issues have not yet been addressed in the literature of tourism management.

Problem description and demand functions

In this section, we first describe the research problem and relevant assumptions, and then derive the demand functions in different competitive situations using the Hotelling model. Different from the basic Hotelling model, we take the effect of tourists' environmental preference into account.

Problem description

In our models, we consider two horizontal competitive tour operators (TOs) who sell tourism products to the end consumers (tourists). Each TO can choose between the traditional tourism strategy (strategy T) and the green tourism innovation strategy (strategy G). When both TOs adopt the traditional tourism strategy (TT), only price competition between them is present. When only one of them chooses the green tourism innovation strategy (TG or GT), it is obvious that the TO who adopts the strategy G is more competitive among eco-conscious tourists. The two TOs are assumed to move simultaneously playing a Nash game and they can constantly adjust their decisions by observing and learning their rival's strategies. We also assume that all parameter information is completely transparent for all participants and the government only subsidizes the green tourism enterprises (if any).

Demand functions

In this subsection, we will derive the demand functions in different competitive situations. We consider the Hotelling duopoly with linear transportation cost and full market coverage, where tourists are uniformly distributed over the interval [0,1] with density equal to one (Hotelling, 1929). It is assumed that the stronger TO (TO 1) stands in the point 0 and the weaker TO (TO 2) lies at the point 1. Furthermore, we assume that every tourist just buys one unit of the green or non-green product, enjoying the following net surplus:

$$\begin{cases} u_1^j = v + mke - p_1^j - tx^j \\ u_2^j = v + nke - p_2^j - t(1 - x^j) \end{cases} \tag{1}$$

Where u_i^j $(i = 1,2; j = TT, GT, TG, GG)$ denotes the visitors' utility by purchasing the tourism service product from TO 1 or TO 2 under different competitive situations. Parameter v is the basic utility of tourism service product, which is the same for all tourists. Parameter p_i^j denotes the sale price set by TO i. Notation x^j represents the tourists' distance to the TO 1 and $t > 0$ is the marginal cost of transportation or product differentiation. Parts mke and nke measure the effect of tourists' environmental preference due to the e provided by TOs, where m and n are binary variables. $m = 0$ $(n = 0)$ means the TO 1 (TO 2) adopts the strategy T, while $m = 1$ $(n = 1)$ denotes that the TO1 (TO2) adopts the strategy G. Parameter e represents the product greenness provided by TOs. Note that we just consider identical and exogenous product greenness to focus on discussing the effect of different green innovation ability of each TO. Parameter k denotes the environmental preference of tourists. The higher the k is, the more the potential green tourists are.

Under the assumption of full market coverage, when the TOs compete only on price, i.e., no one adopts the strategy G, the tourists' utility by purchasing traditional tourism products from TO 1 and TO 2 is respectively: $u_1^{TT} = v - p_1^{TT} - tx^{TT}$ and $u_2^{TT} = v - p_2^{TT} - t(1 - x^{TT})$. Furthermore, the derivation of market demands requires identifying the indifferent consumer located at x^{TT*} such that: $u_1^{TT} = u_2^{TT}$, namely, $v - p_1^{TT} - tx^{TT*} = v - p_2^{TT} - t(1 - x^{TT*})$. Therefore, we can obtain the demand of TO 1 as $D_1^{TT} = x^{TT*} = \frac{p_2^{TT} + t - p_1^{TT}}{2t}$, and the demand of TO 2 as $D_2^{TT} = 1 - x^{TT*} = 1 - \frac{p_2^{TT}+t-p_1^{TT}}{2t}$. When TO 1 adopts the strategy G while TO 2 chooses the strategy T, the utility of tourists buying green product from TO 1 is $u_1^{GT} = v + ke - p_1^{GT} - tx^{GT}$ while $u_2^{GT} = u_2^{TT}$. Setting $u_1^{GT} = u_2^{GT}$, we can derive the demand function of each TO as: $D_1^{GT} = x^{GT*} = \frac{p_2^{GT}+t+ke-p_1^{GT}}{2t}$ and $D_2^{GT} = 1 - x^{GT*} = 1 - \frac{p_2^{GT}+t+ke-p_1^{GT}}{2t}$. In the TG strategy scenario, we can know that the tourists' utilities are $u_1^{TG} = u_1^{TT}$ and $u_2^{TG} = v + ke - p_2^{TG} - t(1 - x^{TG})$. Using a similar method, we can obtain the demand of TO 1 as $D_1^{TG} = x^{TG*} = \frac{p_2^{TG}+t-ke-p_1^{TG}}{2t}$ and the demand of TO 2 as $D_1^{TG} = 1 - x^{TG*} = 1 - \frac{p_2^{TG}+t-ke-p_1^{TG}}{2t}$. Under the GG scenario, the utilities of tourists buying products from TO 1 and TO 2 are: $u_1^{GG} = u_1^{GT}$ and $u_2^{GG} = u_2^{TG}$. Finally, we can obtain the following demand functions: $D_1^{GG} = x^{GG*} = \frac{p_2^{GG}+t-p_1^{GG}}{2t}$, $D_2^{GG} = 1 - x^{GG*} = 1 - \frac{p_2^{GG}+t-p_1^{GG}}{2t}$.

One-shot duopoly game among TOs

In this section, we model the one-shot duopoly game between the TOs and derive the pricing decisions of green and/or non-green products under different competitive situations. As mentioned earlier, the treatment cost of green products is often related to the number of tourists, such as controlling carbon emission or waste disposal. Consistent with the literature, we model the unit variable cost of green tourism innovation as a quadratic function $\mu_i e^2$ $(i = 1,2)$, where the μ_i is cost coefficient, representing the TO's green innovation ability. The higher the μ_i, the lower the efficiency of TO's green innovation. This quadratic function has been proved to be reasonable and widely used by many researchers (e.g., Guo et al., 2013; Long and Shi, 2017; Zhu and He, 2016). Furthermore, we further assume $\mu_1 < \mu_2$, meaning that TO 1 has a cost advantage compared to TO 2. It is assumed that the other relative cost of the traditional/green tourism product except for the green tourism innovation cost is c_0. As a result, the unit average cost of traditional (green) tourism product is c_0 $(c_0 + \mu_i e^2)$. To simplify the mathematic models, we assume $c_0 = 0$ without loss of generality due to the fact that parameter c_0 does not affect the main theoretical results of our models (Guo et al., 2013). Under some practical situations, tour managers may ignore the marginal cost of service (e.g., air seat, hotel room) when making operational decisions due to it is sunken investment. Hence, this simplification is reasonable to a large extent.

We hereafter let the superscript $*$ denote the optimal solutions and π_i^j represent the profit of TO i in different strategy combinations. We first study the price competition between TO 1 and TO 2 under TT strategy combination. Based on the demand functions derived earlier, the optimization problems of two TOs are:

$$\begin{cases} \max_{p_1^{TT}} \pi_1^{TT} = p_1^{TT}\left(\frac{p_2^{TT}+t-p_1^{TT}}{2t}\right) \\ \max_{p_2^{TT}} \pi_2^{TT} = p_2^{TT}(1-\frac{p_2^{TT}+t-p_1^{TT}}{2t}) \end{cases} \tag{2}$$

By solving Equation (2), the equilibrium prices of TOs are: $p_1^{TT*} = p_2^{TT*} = t$ and the profits of these TOs are expressed as: $\pi_1^{TT*} = \pi_2^{TT*} = \frac{t}{2}$. It means that the TOs will set the same prices and attain equal market shares and profits. All proofs of the four strategy combinations are provided in Appendix A.

Under the pressure of environmental protection, some enterprises may be motivated to implement green tourism innovation to attract more green tourists. Suppose that TO 1 selects the strategy G, while TO 2 chooses the strategy T. Based on the corresponding demand functions in subsection 'Demand functions', we can obtain the following profit functions of TOs: $\pi_1^{GT} = (p_1^{GT} - \mu_1 e^2)\left(\frac{p_2^{GT}+t-p_1^{GT}+ke}{2t}\right)$ and $\pi_2^{GT} = p_2^{GT}\left(1-\frac{p_2^{GT}+t-p_1^{GT}+ke}{2t}\right)$. Contrary to the GT strategy, if TO 1 selects the strategy T while TO 2 adopts the strategy G, the profit functions of two TOs are: $\pi_1^{TG} = p_1^{TG}\left(\frac{p_2^{TG}+t-p_1^{TG}-ke}{2t}\right)$ and $\pi_2^{TG} = (p_2^{TG} - \mu_2 e^2)\Big(1-$

$\frac{p_2^{TG}+t-p_1^{TG}-ke}{2t}$). If both TOs adopt the strategy G, their profit functions can be expressed as: $\pi_1^{GG} = (p_1^{GG} - \mu_1 e^2)(\frac{p_2^{GG}+t-p_1^{GG}}{2t})$ and $\pi_2^{GG} = (p_2^{GG} - \mu_2 e^2)(1 - \frac{p_2^{GG}+t-p_1^{GG}}{2t})$. Using a similar method as before, we can derive the optimal prices, demands and profits of TOs for the three cases above, which are also listed in Table 1.

Table 1. Equilibrium solutions in different competitive situations

	Strategy TT	Strategy GT	Strategy TG	Strategy GG
p_1^*	t	$\frac{(ek+3t+2e^2\mu_1)}{3}$	$\frac{(3t+e^2\mu_2-ek)}{3}$	$\frac{(3t+2e^2\mu_1+e^2\mu_2)}{3}$
p_2^*	t	$\frac{(3t+e^2\mu_1-ek)}{3}$	$\frac{(ek+3t+2e^2\mu_2)}{3}$	$\frac{(3t+e^2\mu_1+2e^2\mu_2)}{3}$
q_1^*	1/2	$\frac{ek+3t-e^2\mu_1}{6t}$	$\frac{3t+e^2\mu_2-ek}{6t}$	$\frac{3t-e^2\mu_1+e^2\mu_2}{6t}$
q_2^*	1/2	$\frac{3t+e^2\mu_1-ek}{6t}$	$\frac{ek+3t-e^2\mu_2}{6t}$	$\frac{3t+e^2\mu_1-e^2\mu_2}{6t}$
π_1^*	$\frac{t}{2}$	$\frac{(ek+3t-e^2\mu_1)^2}{18t}$	$\frac{(3t+e^2\mu_2-ek)^2}{18t}$	$\frac{(3t+e^2\mu_2-e^2\mu_1)^2}{18t}$
π_2^*	$\frac{t}{2}$	$\frac{(3t+e^2\mu_1-ek)^2}{18t}$	$\frac{(ek+3t-e^2\mu_2)^2}{18t}$	$\frac{(e^2\mu_1+3t-e^2\mu_2)^2}{18t}$

To ensure that the equilibrium solutions of TOs under four competitive situations (TT, GT, TG, and GG) are all non-negative, the environmental preference of tourists should satisfy $\frac{\mu_2 e^2-3t}{e} \le k \le \frac{\mu_1 e^2+3t}{e}$ and $e^2\mu_2 \le 3t + e^2\mu_1$. These two conditions are the basic participation constraints of the two TOs. Comparing the solutions in different competition situations, we can have the following proposition.

Proposition 1. *In the one-shot duopoly game:*

(1) *When the environmental preference of tourists is very high ($k > \frac{\mu_1 e^2+3t}{e}$ for TO 1 or $k > \frac{\mu_2 e^2+3t}{e}$ for TO 2), a green tourism innovation pioneer has an opportunity to monopolize the market by implementing the strategy G.*

(2) *When both of TOs adopt the strategy G, environment-friendly tourists would pay higher*

prices for green products ($p_1^{TT*} < p_1^{GG*}$ and $p_2^{TT*} < p_2^{GG*}$) and the stronger TO will attract more tourists ($q_1^{GG*} > \frac{1}{2} > q_2^{GG*}$).

The proofs of Proposition 1 are straightforward by comparing the equilibrium solutions shown in Table 1. Proposition 1(1) indicates that the pioneer of green tourism innovation could monopolize the market when the environmental preference of tourists is high enough. Therefore, TOs facing environment-friendly tourists should adopt green tourism innovation earlier, or they may be squeezed out of the market. Proposition 1(2) shows that both TOs may pass parts of their innovation costs to the tourists resulting in higher sale prices, which is consistent with the reality that we must invest additional resources to promote sustainable development and environment-friendly tourists would pay extra for the green products (Abdallah et al., 2012; Zhu et al., 2007). Thanks to its cost advantage, TO 1 will set a lower price to win a larger market share as well as a larger profit. This implies that maintaining stronger innovation ability is always beneficial for companies to deal with an evolutional market. Notice that both TOs achieve lower profits in the GG scenario than the TT scenario. The reason behind is that they have to bear parts of green tourism innovation cost.

Evolutionary analysis of TOs

As previously mentioned, the one-shot strategy is not necessarily optimal for TOs under the bounded rationality assumptions when the game players' decisions are interdependent. The TOs ultimately determine the optimal and stable equilibrium strategy by keeping learning and imitating competitors' tactics over time. Therefore, it is necessary to analyze the strategy evolutionary process of each participant. In what follows, we will establish evolutionary game models to investigate the strategic interaction between the TOs. Since the profits of TOs are symmetric in the TT situation, for simplicity, we let $\pi_1^{TT*} = \pi_2^{TT*} = \pi^{TT}$. Hence, the corresponding payoff matrix can be established, as shown in Table 2.

Table 2. Payoff matrix of TOs

TO-1	TO-2	
	G-strategy (y)	T-strategy ($1-y$)
G-strategy (x)	(π_1^{GG}, π_2^{GG})	(π_1^{GT}, π_2^{GT})
T-strategy ($1-x$)	(π_1^{TG}, π_2^{TG})	(π^{TT}, π^{TT})

It is assumed that the probability of TO 1 adopting strategy G is x, then that of TO 1 selecting the strategy T is $1-x$. Likewise, we let y and $1-y$ denote the probability of TO 2 adopting strategy G and strategy T, respectively. According to the replicator dynamic equation, the increasing rate $\frac{dx/dt}{x}$ of the TO 1 adopting strategy G is equal to the difference between earnings $\boldsymbol{a} \bullet A_1 \bullet (y, 1-y)^T$ and the average revenue of the TOs $(x, 1-x) \bullet A_1 \bullet (y, 1-y)^T$ where $\boldsymbol{a} = (1,0)$ indicates that TO 1 adopts strategy G with a probability 1, and A_1 denotes the profit matrix $\begin{bmatrix} \pi_1^{GG} & \pi_1^{GT} \\ \pi_1^{TG} & \pi^{TT} \end{bmatrix}$ of TO 1 (Yi and Yang, 2017). Consequently, we obtain the replicator dynamic equation for TO 1:

$$F(x) = \frac{dx}{dt} = x\big(\boldsymbol{a} - (x, 1-x)\big) \cdot A_1 \cdot (y, 1-y)^T \tag{3}$$

Where $F(x)$ represents the change rate of the TO 1 using strategy G. Furthermore, $F'(0) < 0$ shows that the proportion of TO 1 selecting strategy G evolves to 0 over time, while $F'(1) < 0$ indicates that it evolves to 1 (Xiao and Chen, 2009). Equation (4) indicates that TOs would imitate and learn the behavior of achievers to generate higher profits. If the profit obtained by one TO who adopts the strategy G is higher than the average earnings of other strategies, the proportion of TO selecting this strategy increases; otherwise, the proportion decreases. According to Table 2, Equation (3) can be calculated and finally expressed as follows:

$$F(x) = \frac{dx}{dt} = x(1-x)\{(\pi_1^{GG} + \pi^{TT} - \pi_1^{GT} - \pi_1^{TG})y + \pi_1^{GT} - \pi^{TT}\} \tag{4}$$

Similarly, the replicator dynamic equation of TO 2 is:

$$F(y) = \frac{dy}{dt} = y(1-y)\{(\pi_2^{GG} + \pi^{TT} - \pi_2^{GT} - \pi_2^{TG})x + \pi_2^{TG} - \pi^{TT}\} \tag{5}$$

The specific simplification processes are presented in Appendix B.

Strategy stability analysis of TO1

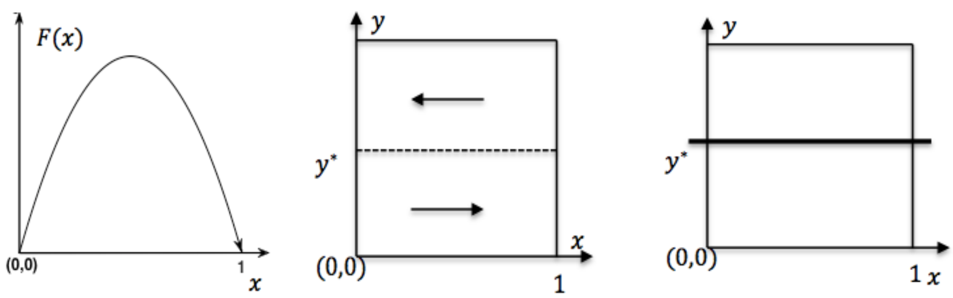
We first take TO 1 into consideration to demonstrate the dynamic evolutionary process. For lucidity and simplicity, we define $\Delta L \overset{\text{def}}{=} \pi_1^{GG} - \pi_1^{TG}$, $\Delta n \overset{\text{def}}{=} \pi_1^{GT} - \pi^{TT}$ and the difference between ΔL and Δn as $\Delta m \overset{\text{def}}{=} \Delta L - \Delta n = \pi_1^{GG} + \pi^{TT} - \pi_1^{GT} - \pi_1^{TG}$. We let $y^* = -\frac{\Delta n}{\Delta m}$, which leads to $F(x) = 0$. It can be concluded from the above definitions that $|y^*| \leq 1$. From Table 1, we can obtain $\Delta L = \frac{-e(k-e\mu_1)(ek-6t+e^2\mu_1-2e^2\mu_2)}{18t}$, $\Delta n = \frac{e(k-e\mu_1)(ek+6t-e^2\mu_1)}{18t}$, and $\Delta m = -\frac{e^2(k-e\mu_1)(k-e\mu_2)}{9t}$, where the ΔL can be interpreted as the decision equation whether a TO should adopt the strategy G or not when the opponent has adopted the strategy G. Notation Δn can be interpreted as the decision equation that helps the TO make a product strategy when his competitor has adopted the strategy T. Δm denotes the variation relationship between $F(x)$ and y. We have the following Proposition 2, which shows the strategy stability of TO 1.

Proposition 2.

(1) *When* $\frac{e^2\mu_2-3t}{e} < k < e\mu_1$, $x^* = 0$ *is an ESS. When* $e\mu_1 < k < e\mu_2$, $x^* = 1$ *is an ESS.*

(2) *When* $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$, *if* $y > y^*$, $x^* = 0$ *is an ESS; if* $y < y^*$, $x^* = 1$ *is an ESS.*

(3) *When* $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$, *and* $y = y^*$, *any initial proportion of TO 1 adopting the strategy G is the ESS.*



(a) $e\mu_1 < k < e\mu_2$ (b) $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$ (c) $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$, and $y = y^*$

Fig. 1. Strategy evolutionary paths of TO 1

Note: The arrow direction represents the strategy evolutionary trend.

From Proposition 2, we can attain the following results and use Fig. 1 to facilitate our discussion. Differentiating Equation (5) with respect to x, we can obtain $F'(x) = (1 - 2x)\{\Delta my + \Delta n\}$. First, when $\frac{e^2\mu_2-3t}{e} < k < e\mu_1$, it can be verified that $\Delta my + \Delta n < 0$ is true for any y, and $F'(x)|_{x=0} < 0$. In this case, TO 1 finally adopts the strategy T no matter what strategy TO 2 selects. While $e\mu_1 < k < e\mu_2$, we can find that $\Delta my + \Delta n > 0$ holds for any y, and $F'(x)|_{x=1} < 0$. This means that TO 1 would select the strategy G in the long run. In the above two cases, it is demonstrated that competition can't affect the decision of green tourism innovation of TO 1. In other words, TO 1 can make product decisions without considering his competitor's strategies. Second, when $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$ and $y \neq y^*$, we can infer that the competitor's strategy might influence TO 1's decision. Moreover, the higher initial proportion of TO 2 adopting the strategy G is, the lower proportion of TO 1 adopting the strategy G is. Namely, TO 1 would adopt opposite strategy from that of TO 2. In this scenario, the stronger TO has to consider the rival's irrational decision. The possible reason is that when the environmental preference is very high, the weaker TO may adopt a disruptive price strategy to capture some market share due to his irrational behavior. As a result, the stronger TO may give up some parts of market share so as not to be subject to greater irrational competition. Third, when $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$ and $y = y^*$, any strategy of TO 1 is stable. That means the proportion of TO 1 adopting strategy G does not change over time. To sum up, TO 1 makes a green tourism innovation decision mainly depending on his own profits and rarely considering his competitor's strategy.

Strategy stability analysis of TO2

As in previous subsection, we can define $\Delta\overline{L} \overset{\text{def}}{=} \pi_2^{GG} - \pi_2^{GT}$, $\Delta\overline{n} \overset{\text{def}}{=} \pi_2^{TG} - \pi^{TT}$ and the decrement between $\Delta\overline{L}$ and $\Delta\overline{n}$ as $\Delta\overline{m} \stackrel{\text{def}}{=} \Delta\overline{L} - \Delta\overline{n} = \pi_2^{GG} + \pi^{TT} - \pi_2^{GT} - \pi_2^{TG}$. Moreover, we let $x^* = -\frac{\Delta\overline{n}}{\Delta\overline{m}}$, which makes sure $F(y) = 0$ except for $y = 0$ or $y = 1$. It can be proved that $|x^*| \leq 1$. According to Table 1 and after some simplifications, we can have $\Delta\overline{L} = \frac{-e(k-e\mu_2)(ek-6t+e^2\mu_2-2e^2\mu_1)}{18t}$, $\Delta\overline{n} = \frac{e(k-e\mu_2)(ek+6t-e^2\mu_2)}{18t}$ and $\Delta\overline{m} = -\frac{e^2(k-e\mu_1)(k-e\mu_2)}{9t}$.

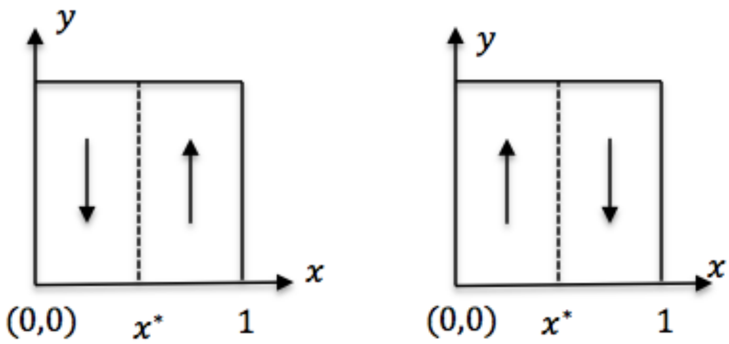
Proposition 3.

(1) *When* $\frac{e^2\mu_2-3t}{e} < k < e\mu_1$, *then* $y = 0$ *is the ESS.*

(2) *When* $e\mu_1 < k < e\mu_2$, *if* $x > x^*$, $y = 1$ *is the ESS; if* $x < x^*$, $y = 0$ *is the ESS.*

(3) *When* $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$, *if* $x > x^*$, $y = 0$ *is the ESS; if* $x < x^*$, $y = 1$ *is the ESS.*

(4) *When* $e\mu_1 < k < e\mu_2$ *or* $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$, *and* $x = x^*$, *then any initial proportion of TO 2 adopting strategy G is the ESS.*



(a) $e\mu_1 < k < e\mu_2$ (b) $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$

Fig. 2. Strategy evolutionary paths of TO 2

Fig. 2 is used to illustrate our results. Proposition 3(1) shows that when the environmental preference of tourists is very low, TO 2 finally adopts the traditional tourism strategy without considering the decision of TO 1. This result is intuitive because the TO with cost disadvantage cannot capture enough market share to make up its green cost. When $e\mu_1 < k < e\mu_2$ (or $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$) and $y \neq y^*$, it can be concluded that TO 1's strategy would significantly affect TO 2's decision. Concretely, when $e\mu_1 < k < e\mu_2$, TO 2 would like to adopt the same strategy with TO 1. Namely, TO 2 will follow TO 1 to implement green tourism innovation when environmental preference is moderate. Conversely, when $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$, we can find that the higher initial proportion of TO 1 adopting strategy G, the lower that of TO 2 is. It promulgates that the ratio of TO 2 adopting strategy G is negatively related to that of TO 1 when environmental preference is relatively high. Finally, when $\mu_1 < k < e\mu_2$ or $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$ $(\Delta\overline{m} \cdot \Delta\overline{n} < 0)$ and $x = x^*$, any strategy of TO 2 is stable. That is to say, the proportion of TO 2 adopting strategy G or T does not change over time. Contrary to TO 1, the TO 2 makes a product strategy largely depending on TO 1's decision behavior.

ESS analysis among TOs

Based on the above analysis of strategy stability, we can conclude that each participant's decision is influenced by the opponent's strategy to some extent. In this subsection, we will discuss the ESS of TOs in different competitive situations. From the replicator dynamic Equations (4) and (5), we can see that this dynamic system has five possible equilibrium points: (0,0)(0,1)(1,0)(1,1) (x^*, y^*). From the stability theorem of differential equation, when trace TrJ and determinant $DetJ$ of the Jacobi matrix satisfy $TrJ < 0$ and $DetJ > 0$, the strategy is an ESS (Friedman, 1991). Therefore, we derive the Jacobi matrix J of replicator dynamic equations of TOs as follows:

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} \end{bmatrix} = \begin{bmatrix} (1-2x)(\Delta my + \Delta n) & x(1-x)\Delta m \\ y(1-y)\Delta\overline{m} & (1-2y)(\Delta\overline{m}x + \Delta\overline{n}) \end{bmatrix} \tag{6}$$

From the Jacobi matrix J, we can find the TrJ and $DetJ$ as follows:

$$\begin{cases} TrJ = (1-2x)(\Delta my + \Delta n) + (1-2y)(\Delta\overline{m}x + \Delta\overline{n}) \\ DetJ = (1-2x)(\Delta my + \Delta n)(1-2y)(\Delta\overline{m}x + \Delta\overline{n}) - x(1-x)\Delta my(1-y)\Delta\overline{m} \end{cases} \tag{7}$$

By distinguishing the signs of TrJ and $DetJ$, we can obtain the following Proposition 4, which demonstrates the ESS of TOs under different conditions. The relevant proofs are listed in Appendix B.

Proposition 4.

(1) *When* $\frac{e^2\mu_2-3t}{e}<k<e\mu_1$, $(x,y)=(0,0)$ *is the ESS;*

(2) *When* $e\mu_1<k<e\mu_2$, $(x,y)=(1,0)$ *is the ESS;*

(3) *When* $e\mu_2<k<\frac{e^2\mu_1+3t}{e}$, $(x,y)=(1,1)$ *is the ESS;*

(4) $(x,y)=(0,1)$ *or* (x^*,y^*) *is not the ESS under any condition;*

Proposition 4 shows the local stability of this system and its corresponding conditions. It is unlikely that both TOs adopt the strategy G in the long run when the environmental preference of tourists is low or moderate. Under the long-term repeated game, when the environmental preference is very low, both TOs will adopt the strategy T. However, if the environmental preference is sufficiently high, both will select the strategy G. The reasons are that when the tourists' environmental preference is very low, the TOs cannot capture sufficient tourists to make up their green cost so that no TOs would participate in green tourism. This phenomenon is not uncommon in developing countries where the tourists are more sensitive to the price and have lower environmental awareness. On the contrary, if the tourists have higher environmental awareness, the tour firms will spontaneously conduct green tourism innovation under market competition. Note that when the environmental preference is moderate, the stronger TO will adopt the strategy G, but the weaker TOs may try to select strategy T to avoid directly completing with the stronger TO. The potential reason is that weaker TO is more sensitive to smaller markets and more susceptible to other firms' behavior. Past studies have indicated that adopting product differentiation strategy could improve a firm's competitiveness and viability (Agrawal and Bellos, 2016; Zhu and He, 2016; Yi and Yang, 2017). This result also can be explained by Proposition 3, which shows that TO 1's decisions always influence TO 2's. However, the stronger TO is more concerned about its profit. After long-term imitating and learning behavior, TO 1 will conduct green tourism innovation due to its cost advantage. After understanding the TO 1's decision, the TO 2 will adopt opposite strategy. In practical operation management, relatively weak TOs often focus on some small market for survival. The following Table 3 shows the strategy stability of TOs under the conditions mentioned in Proposition 4(1). Other proofs are shown in Appendix B.

Table 3. The stability of each local equilibrium points under $\frac{e^2\mu_2-3t}{e} < k < e\mu_1$.

	$DetJ$	Sign	TrJ	Sign	Local stability
(0,0)	$\Delta n \cdot \Delta\overline{n}$	$+$	$\Delta n + \Delta\overline{n}$	$-$	ESS
(0,1)	$-\Delta L \cdot \Delta\overline{n}$	$-$	$\Delta L - \Delta\overline{n}$	$\pm$	Saddle point
(1,0)	$-\Delta\overline{L} \cdot \Delta n$	$-$	$\Delta\overline{L} - \Delta n$	$\pm$	Saddle point
(1,1)	$\Delta L \cdot \Delta\overline{L}$	$+$	$-(\Delta L + \Delta\overline{L})$	$+$	Unstable

To validate the theoretical findings above and gain more managerial implications, we conduct numerical studies to depict the evolutionary paths of the dynamic system. According to Proposition 4, we set relevant parameters as $t = 0.1, e = 1, \mu_1 = 0.4$ and $\mu_2 = 0.6$. To observe the effect of tourists' environmental preference, we let the parameter k change over the interval [0.3, 0.73), and the initial proportion x_0 change from 0.1 to 0.9 with steps 0.2. Setting initial proportion y_0 as $0.2, 0.4, 0.6,$ and 0.8, respectively, we can obtain Fig. 3.

From Fig. 3, we can conclude that the dynamical system will evolve into ESS (0,0), ESS (1,0) or ESS (1,1) as environmental preference k varies. To be more specific, when the environmental preference is very low, the system will evolve into local stability point (0,0). When the tourists' environmental preference is moderate, it will evolve into local stability point (1,0). If the environmental preference is very high, the system will finally evolve into ESS (1,1). Furthermore, the initial ratio of each TO adopting the green tourism innovation strategy will not affect the final evolutionary states of this system, but it may influence the evolutionary trajectories. Notice that when the initial ratio is relatively low, the evolutionary speed of evolving into ESS (0,0) is relatively fast. On the contrary, it evolves into ESS (1,1) faster. It also depicts that the initial proportion of each TO selecting strategy T or G would influence the rival's evolutionary speed and path, but the dynamical system will finally evolve into the stable states in the long term.

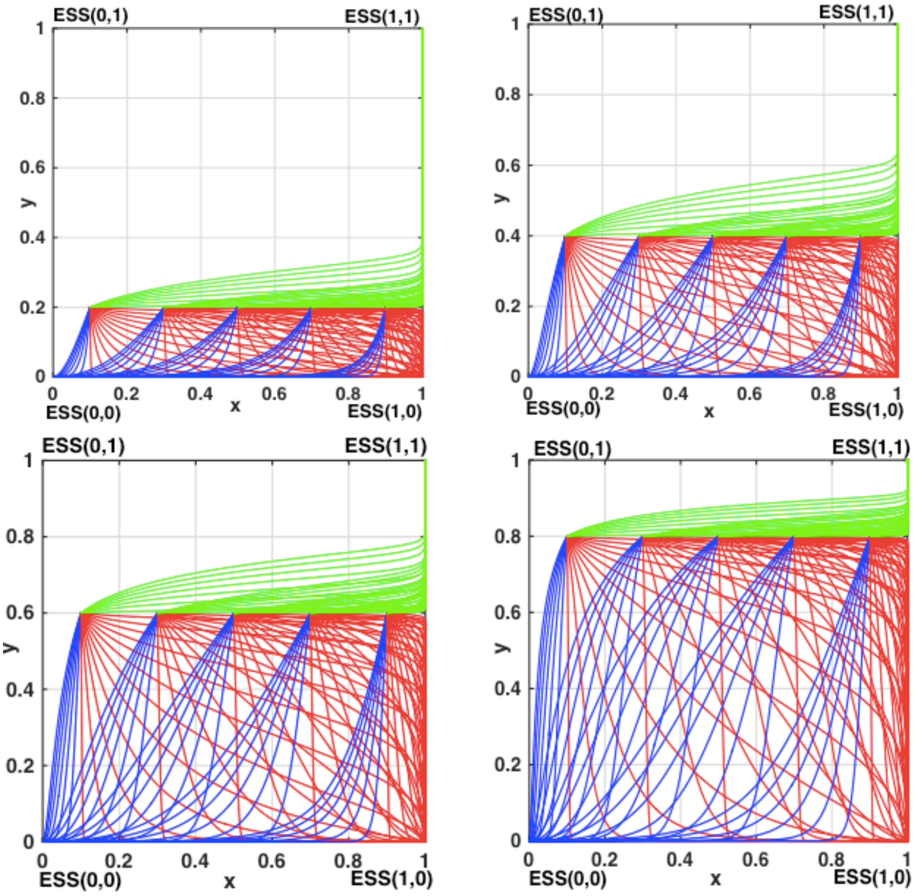


Fig. 3. The evolutionary diagram of the dynamical system with $y_0 = 0.2, 0.4, 0.6$ and 0.8

ESS of TOs with government subsidy

Based on our analysis and discussions so far, we can conclude that when the tourists' environmental preference is low or moderate, it is difficult to motivate two TOs to implement green tourism innovation simultaneously only because of market competition. This will hamper the further development of green tourism. Therefore, it is essential for the government to subsidize the TOs who implement green tourism innovation. We let parameter s denote the subsidy implemented by government. The payoff matrix of TOs with government green subsidy is established in Table 4.

Table 4. Payoff matrix of TOs with government green subsidy

TO-1	TO-2	
	G-strategy (y)	T-strategy $(1-y)$
G-strategy (x)	$(\pi_1^{GG}+s, \pi_2^{GG}+s)$	$(\pi_1^{GT}+s, \pi_2^{GT})$
T-strategy $(1-x)$	$(\pi_1^{TG}, \pi_2^{TG}+s)$	(π^{TT}, π^{TT})

From Table 4, using a similar method as before, we can obtain the replicator dynamic equation under government subsidy as follows:

$$\begin{cases} F(x)_s = x(1-x)\{(\pi_1^{GG} + \pi^{TT} - \pi_1^{GT} - \pi_1^{TG})y + \pi_1^{GT} + s - \pi^{TT}\} \\ F(y)_s = y(1-y)\{(\pi_2^{GG} + \pi^{TT} - \pi_2^{GT} - \pi_2^{TG})x + \pi_2^{TG} + s - \pi^{TT}\} \end{cases} \tag{8}$$

Appendix C shows the simplification processes of Equation (8) and the Jacobi matrix J_s and trace TrJ_s and determinant $DetJ_s$. By checking the signs of TrJ_s and $DetJ_s$, we can have the following Proposition 5, which reveals the ESS of TOs under different government subsidies. The relevant proofs are provided in Appendix C.

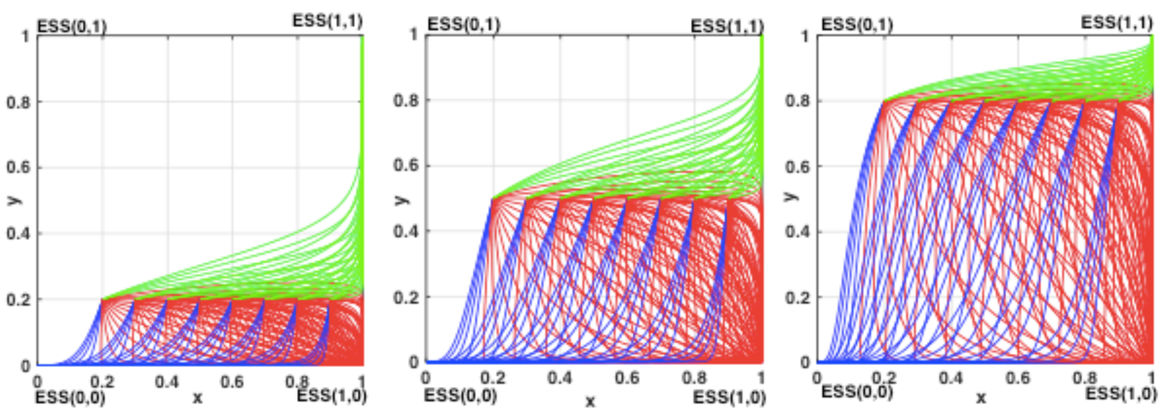
Proposition 5.

(1) *When* $\frac{e^2\mu_2 - 3t}{e} < k < e\mu_1$, *if* $s < -\Delta n$, *government subsidy is almost ineffective; if* $-\Delta n < s < -\Delta\overline{L}$, *the government subsidy is only effective for stronger TOs; only when* $s > -\Delta\overline{L}$ *can the dynamic system evolve into the ESS* (1,1).

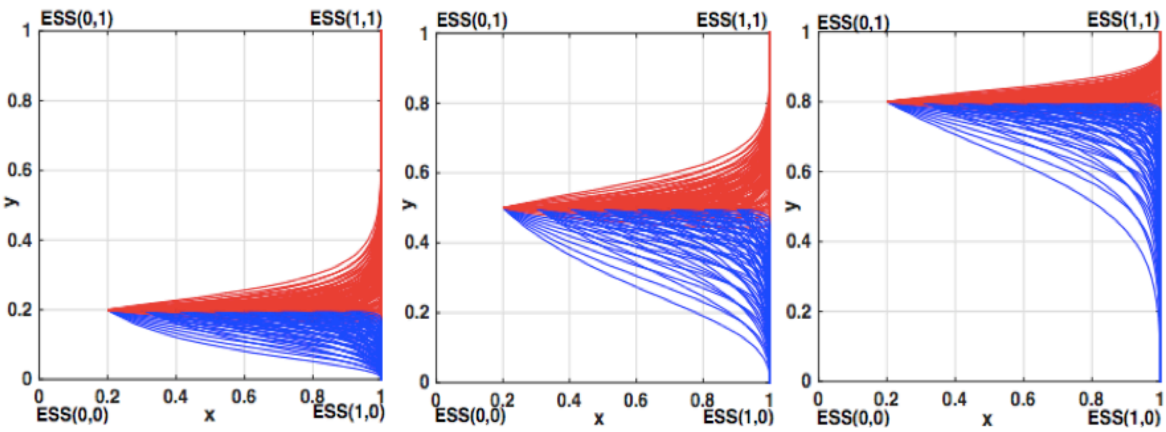
(2) *When* $e\mu_1 < k < e\mu_2$, *the government should mainly subsidize weaker TOs and make sure that the subsidy satisfies* $s > -\Delta\overline{L}$ *so that* $(x, y) = (1,1)$ *is the ESS.*

According to Proposition 5, the government subsidy can influence the TOs' decisions to a certain extent. Specifically, when the government subsidy is very low, it may only affect the TOs' behavior in the short term, but it cannot work in the long term. Consequently, the TOs still pursue traditional tourism. When the government subsidy is moderate, it can motivate the stronger TO to adopt the strategy G, but it is invalid for the weaker TO. From this point, if the government has insufficient budget to subsidize tour firms, more attention should be paid to the TOs with higher innovative ability so that the other TOs may automatically implement green tourism innovation due to market competition. In this setting, the lowest subsidy offered by government is $-\Delta n$. When the government subsidy is high enough to compensate for the green tourism innovation cost, both weaker and stronger TOs would like to select green tourism. According to Proposition 5 (2), we can conclude that when the tourists' environmental preference is moderate, the government should focus on encouraging the weaker TO to implement green tourism. The optimal subsidy of government is $-\Delta\overline{L}$, which can compensate for the green tourism innovation cost of the weaker TO. Thus, it is sensible of government to set up appropriate subsidy schemes for different situations. To sum up, the primary means is to motivate the stronger TOs to implement green tourism innovation when the environmental preference of tourists is relatively low. On the contrary, the government should mainly subsidize the weaker TOs when the environmental preference of tourists is relatively high.

In order to further observe the strategy evolutionary trajectories of TOs and the effect of government subsidy, we employ numerical studies to better understand our theoretical findings. From Proposition 5, we set the same basic parameter values used in subsection 'ESS analysis among TOs' and $k = 0.35$ for Fig. 4(a) and $k = 0.5$ for Fig. 4(b). To focus on the impacts of the government subsidy on TOs' decisions, we vary the subsidy level s to observe the effectiveness of government subsidy in three possible scenarios: s is very low (blue lines) or moderate (red lines) or relatively high (green lines). The illustration results are shown in Fig. 4 (a).



(a) $\frac{e^2\mu_2-3t}{e} < k < e\mu_1$



(b) $e\mu_1 < k < e\mu_2$

Fig. 4. The evolutionary path diagram of the dynamical system with government subsidy change

From Fig. 4, we can obtain the following managerial insights. When the government subsidy is very low, it can't change the original evolutionary stable states, which means government subsidy is ineffective in this case. However, when the subsidy is high enough, the subsidy policy works to some extent. In particular, when the green subsidy is moderate, the dynamic system finally evolves into the ESS (1,0). In this scenario, the government subsidy policy can only motivate the stronger TOs to implement green tourism. When subsidy is more than $-\Delta\overline{L}$, it can motivate both TOs to adopt the strategy G even if the environmental preference of tourists is low or moderate. In short, only with sufficiently high subsidy level can the government successfully promote sustainable tourism development. Recall that when the government subsidy is moderate (red lines in Fig. 4), the evolutionary trajectories are not monotonically increasing. It implies that different initial state of each TO selecting strategy G and/or government subsidy may motivate the TOs to adopt different strategies in the short term, but the dynamical system will eventually evolve into the stable states in the long term.

Conclusions and managerial implications

This article focuses on the strategic interaction of green tourism innovation and price competition between two asymmetrical tour operators (TOs). Employing the classical Hotelling model and Evolutionary Game Theory, we first derive the demand functions in different competitive settings considering key potential factors such as the tourists' environmental preference and government green subsidy. We then build a one-shot duopoly game model and two evolutionary game models with or without the government's green subsidy.

Our analyses and results highlight that a green tourism innovation pioneer has an opportunity to monopolize the burgeoning market as long as the environmental preference of tourists is sufficiently high. We also show that the presence of environmental preference may damage the TOs when they implement strategy G simultaneously. Moreover, when the tourists' environmental preference is moderate, competition will significantly affect the decisions of TOs. When it is high enough, the stronger TO would take its opponent's decisions into account but the weaker TO may not adopt the strategy G in the long run. Specifically for TO 2, when the environmental preference of tourists is moderate, the rate of weaker TO adopting green tourism innovation increases in that of stronger TO. On the contrary, the two adoption rates are negatively related when the environmental preference is sufficiently high.

The major contributions of our research are twofold in terms of both theory and practice. First and foremost, a Hotelling model with green tourism innovation is developed to measure the effect of tourists' environmental preference on demand functions, while many previous papers are empirical or case based (e.g., Chen and Tung, 2014; Han and Yoon, 2015; Rahman and Reynolds, 2016). These papers generally conclude that environmental awareness would affect tourists' purchasing behavior. Our findings are more specific and illustrate the different possible impacts of environmental preference on TOs' product and pricing strategies. Secondly, we establish a one-shot game and two evolutionary game models to study the green tourism innovation interaction and pricing strategies based on the bounded rationality assumption theory. This is a significant theoretical contribution because many previous studies have investigated the pricing strategy in the tourism industry with the complete rationality assumption from a short-term perspective (Chung, 2000; García and Tugores, 2006; Guo et al., 2013; Long and Shi, 2017). From a long-term perspective, our paper investigates the pricing of green or non-green tourism products and identifies potential government subsidy policies that can promote green tourism innovation.

Our research results could provide useful insights for government regulators who are in charge of promoting sustainable tourism. Our findings suggest that to be more effective, the government first choose some highly competitive tourism locations and/or some innovative (stronger) TOs to subsidize. The findings of this paper can also help government regulators understand why some policies are more successful than others. For example, it might be believed that sustainable tourism can be developed faster with subsidies available to more TOs. However, according to our research, when the environmental preference of tourists is relatively low, the government should shift its efforts from all firms to the stronger TOs. Otherwise, it should pay more attention to the weaker ones.

To address the potential limitations of this study, some assumptions used in our models may be relaxed or modified. For example, even though linear transportation cost and full market coverage assumption are widely adopted in the horizontal competition literature, it is worthwhile to further validate our managerial findings with other cost functional forms, such as quadratic cost function. Also, this article focuses on the strategy choice of green tourism innovation with deterministic demand. It is worthwhile studying the horizontal competition innovation with uncertain demand. Furthermore, this paper mainly analyzes the decision-making problem without considering a supply chain structure. Hence, the issue of multi-echelon supply chain structure can be studied in future research. Lastly, our paper mainly utilizes analytical model, so another future research direction is to conduct empirical research to validate our analytical findings.

References

Abdallah, T., Farhat, A., Diabat, A., et al. (2012). Green supply chains with carbon trading and environmental sourcing: formulation and life cycle assessment. *Applied Mathematical Modelling, 36*(9), 4271-4285.

Abrate, G., Fraquelli, G. and Viglia, G. (2012). Dynamic pricing strategies: evidence from European hotels. *International Journal of Hospitality Management, 31*(1), 160-168.

Adriana, B. (2009). Environmental supply chain management in tourism: the case of large tour operators. *Journal of Cleaner Production, 17*(16), 1385-1392.

Agrawal, V. and Bellos, I. (2016). The potential of servicizing as a green business model. *Management Science, 63*(5), 1545-1562.

Blanco, E., Lozano, J. and Rey-Maquieira, J. (2009). A dynamic approach to voluntary environmental contributions in tourism. *Ecological Economics, 69*(1), 104-114.

Buckley, R. (2012). Sustainable tourism: research and reality. *Annals of Tourism Research, 39*(2), 528-546.

Carrillo, J. E., Vakharia, A. J. and Wang, R. (2014). Environmental implications for online retailing. *European Journal of Operational Research, 239*(3), 744-755.

Chan, E. S. W., Hon, A. H. Y., Chan, W., et al. (2014). What drives employees' intentions to implement green practices in hotels? The role of knowledge, awareness, concern and ecological behaviour. *International Journal of Hospitality Management, 40*, 20-28.

Chen, M. F. and Tung, P. J. (2014). Developing an extended theory of planned behavior model to predict consumers' intention to visit green hotels. *International Journal of Hospitality Management, 36*(1), 221-230.

Chu, C. P. and Chung, K. C. (2016). A framework model for assessing sustainability strategies for tourism green supply chain management. *Journal of Testing & Evaluation, 44*(3), 1390-1399.

Chung, K. Y. (2000). Hotel room rate pricing strategy for market share in oligopolistic competition -eight-year longitudinal study of super deluxe hotels in Seoul. *Tourism Management, 21*(2), 135-145.

Dai, R. and Zhang, J. (2017). Green process innovation and differentiated pricing strategies with environmental concerns of south-north markets. *Transportation Research Part E Logistics & Transportation Review, 98*, 132-150.

De Vita, G., Katircioglu, S., Altinay, L., et al. (2015). Revisiting the environmental Kuznets curve hypothesis in a tourism development context. *Environmental Science and Pollution Research*, *22*(21), 16652-16663.

Dong, Y., Ling, L. and Guo, X. (2014). Travel package modeling: optimal bidding strategy of tour operator to cooperative hotels. *Asia Pacific Journal of Tourism Research, 19*(12), 1417-1440.

Droste, N., Hansjürgens, B., Kuikman, P., et al. (2016). Steering innovations towards a green economy: understanding government intervention. *Journal of Cleaner Production, 135*, 426-434.

Dunk, R. M., Gillespie, S. A. and Macleod, D. (2016). Participation and retention in a green tourism certification scheme. *Journal of Sustainable Tourism, 24*(12), 1585-1603.

Friedman, D. (1991). Evolutionary games in economics. *Econometrica, 59*(3), 637-666.

Fong, S. F., Lo, M. C., Songan, P., et al. (2017). Self-efficacy and sustainable rural tourism development: local communities' perspectives from Kuching, Sarawak. *Asia Pacific Journal of Tourism Research, 22*(2), 147-159.

García, D. and Tugores, M. (2006). Optimal choice of quality in hotel services. *Annals of Tourism Research, 33*(2), 456-469.

Ghosh, D. and Shah, J. (2012). A comparative analysis of greening policies across supply chain structures. *International Journal of Production Economics, 135*(2), 568-583.

Guo, X. L. and He, L. (2012). Tourism supply-chain coordination: the cooperation between tourism hotel and tour operator. *Tourism Economics, 18*(6), 1361-1376.

Guo, X., Ling, L., Dong, Y., et al. (2013). Cooperation contract in tourism supply chains: The optimal pricing strategy of hotels for cooperative third party strategic websites. *Annals of Tourism Research, 41*(1), 20-41.

Han, H. and Yoon, H. J. (2015). Hotel customers' environmentally responsible behavioral intention: impact of key constructs on decision in green consumerism. *International Journal of Hospitality Management, 45*, 22-33.

Hansen, M. and Birkinshaw, J. M. (2007). The innovation value chain. *Harvard Business Review, 85*(6), 2-12.

He, P., He, Y. and Xu, F. (2018). Evolutionary analysis of sustainable tourism. *Annals of Tourism Research*, 69, 76-89.

Hotelling, H. (1929). Stability in competition. *Economic Journal, 39*(153), 41-57.

Hou, J., Chen, H. and Xu, J. (2017). External knowledge sourcing and green innovation growth with environmental and energy regulations: evidence from manufacturing in China. *Sustainability, 9*(3), 342.

Huang, G. Q., Song, H. and Zhang, X. (2010). A comparative analysis of quantity and price competitions in tourism supply chain networks for package holidays. *The Service Industries Journal, 30*(10), 1593-1606.

Kammerer, D. (2009). The effects of customer benefit and regulation on environmental product innovation: Empirical evidence from appliance manufacturers in Germany. *Ecological Economics, 68*(8–9), 2285-2295.

Katircioglu, S.T., Feridun, M. and Kilinc, C. (2014). Estimating tourism-induced energy consumption and CO2 emissions: the case of Cyprus. *Renewable & Sustainable Energy Reviews*, *29*, 634-640.

Kuchukova, N., Sadvokasova, K., Salykov, O., et al. (2016). The improvement of the innovation development funding in the Republic of Kazakhstan with regard to international experience. *International Journal of Economic Perspectives*, *10*(4), 244-255.

Lee, K. H. and Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of Cleaner Production,* 108, 534-542.

Liu, J., Nijkamp, P., Huang, X., et al. (2017). Urban livability and tourism development in China: analysis of sustainable development by means of spatial panel data. *Habitat International, 68*, 99-107.

Lockyer, T. (2005). The perceived importance of price as one hotel selection dimension. *Tourism Management, 26*(4), 529-537.

Loiseau, E., Saikku, L., Antikainen, R., et al. (2016). Green economy and related concepts: an overview. *Journal of Cleaner Production, 139*, 361-371.

Long,Y. and Shi, P. (2017). Pricing strategies of tour operator and online travel agency based on cooperation to achieve O2O model. *Tourism Management, 62*, 302-311.

Osloob, M. and Foumani, A. F. (2017). The relationship between market orientation and innovation performance: testing the moderating role of ownership structure. *International Journal of Economic Perspectives*, *11*(1), 1100-1108.

Qi, G. Y., Shen, L. Y., Zeng, S. X., et al. (2010). The drivers for contractors' green innovation: an industry perspective. *Journal of Cleaner Production, 18*(14), 1358-1365.

Rahman, I. and Reynolds, D. (2016). Predicting green hotel behavioral intentions using a theory of environmental commitment and sacrifice for the environment. *International Journal of Hospitality Management, 52*(1), 107-116.

Smith, J. M. and Price, G. R. (1973). The logic of animal conflict. *Nature, 246*(5427), 15-18.

Song, H. Y., Shu, Y. and Huang, G. Q. (2009). Price interactions between theme park and tour operator. *Tourism Economics, 15*(4), 813-824.

Suriñach, J. and Wöber, K. (2017). Introduction to the special focus: cultural tourism and sustainable urban development. *Tourism Economics, 23*(2), 239-242.

Taylor, P. (1998). Mixed strategy pricing behaviour in the UK package tour industry. *International Journal of the Economics of Business, 5*(1), 29-46.

Vargo, S. L. and Lusch, R. F. (2008). Service-dominant logic: continuing the evolution. *Journal of the Academy of Marketing Science, 36* (1), 1–10.

Wang, C., Nie, P. Y., Peng, D. H., et al. (2017). Green insurance subsidy for promoting clean production innovation. *Journal of Cleaner Production, 148*, 111-117.

Weibull, J.W. (1997). *Evolutionary Game Theory.* Cambridge, MA, USA: MIT Press.

Wong, S. K. (2013). The influence of green product competitiveness on the success of green product innovation: empirical evidence from the Chinese electrical and electronics industry. *European Journal of Innovation Management, 15*(4), 468-490.

Xiao, T. and Chen, G. (2009). Wholesale pricing and evolutionarily stable strategies of retailers with imperfectly observable objective. *European Journal of Operational Research, 196*(3), 1190-1201.

Xu, F. and Fox, D. (2014). Modelling attitudes to nature, tourism and sustainable development in national parks: A survey of visitors in China and the UK. *Tourism Management, 45*(1), 142-158.

Yang, L., Ji, J. N. and Chen, K. B. (2016). Game models on optimal strategies in a tourism dual-channel supply chain. *Discrete Dynamics in Nature and Society, 2016* (1), 1-15.

Yi, Y. and Yang, H. (2017). Wholesale pricing and evolutionary stable strategies of retailers under network externality. *European Journal of Operational Research, 259*(1), 37-47.

Zhang, Y., Hafezi, M., Zhao, X., et al. (2017). The impact of development cost on product line design and its environmental performance. *International Journal of Production Economics, 184*, 122-130.

Zheng, G. (1997). Proposing a room pricing model for optimizing profitability. *International Journal of Hospitality Management, 16*(3), 273-277.

Zhu, Q., Sarkis, J. and Lai, K. H. (2007). Green supply chain management: pressures, practices and performance within the Chinese automobile industry. *Journal of Cleaner Production, 15*(11–12), 1041-1052.

Zhu, W. and He, Y. (2016). Green product design in supply chains under competition. *European Journal of Operational Research, 258*(1), 165-180.

Appendix A. Proofs of One-shot duopoly game of TOs

A.1. Proof of strategy TT

It can be proved that the second-order conditions: $\frac{d^2\pi_1^{TT}}{dp_1^{TT}} = \frac{d^2\pi_2^{TT}}{dp_2^{TT}} = -\frac{1}{t} < 0$, which means the optimization problem Equation (2) has optimal solutions. Therefore, setting the first-order conditions to 0 can help us work out the optimal solutions, which are shown below:

$$\begin{cases} \frac{p_2^{TT*}+t-2p_1^{TT*}}{2t} = 0 \\ \frac{p_1^{TT*}+t-2p_2^{TT*}}{2t} = 0 \end{cases} \tag{A1}$$

A.2. Proof of strategy GT

It is obvious that $\frac{\partial^2\pi_1^{GT}}{\partial^2 p_1^{GT}} = \frac{\partial^2\pi_2^{GT}}{\partial^2 p_2^{GT}} = -\frac{1}{t} < 0$. Therefore, we can solve the unique best reaction equations (A2) obtained by taking the derivative of prices on profit functions to find out the optimal solutions.

$$\begin{cases} \frac{ek+t-2p_1^{GT}+p_2^{GT}+e^2\mu_1}{2t} = 0 \\ \frac{-ek+t+p_1^{GT}-2p_2^{GT}}{2t} = 0 \end{cases} \tag{A2}$$

A.2. Proof of strategy TG

Likewise, according to the profits functions π_1^{TG} and π_2^{TG}, we can have: $\frac{\partial^2\pi_1^{TG}}{\partial^2 p_1^{TG}} = \frac{\partial^2\pi_2^{TG}}{\partial^2 p_2^{TG}} = -\frac{1}{t} < 0$. By solving the following reaction equations, we can obtain the optimal solutions.

$$\begin{cases} \frac{-ek+t-2p_1^{TG}+p_2^{TG}}{2t} = 0 \\ \frac{ek+t+p_1^{TG}-2p_2^{TG}+e^2\mu_2}{2t} = 0 \end{cases} \tag{A3}$$

A.3. Proof of strategy GG

From the profits functions π_1^{GG} and π_2^{GG}, we can have: $\frac{\partial^2\pi_1^{GG}}{\partial^2 p_1^{GG}} = \frac{\partial^2\pi_2^{GG}}{\partial^2 p_2^{GG}} = -\frac{1}{t} < 0$. Hence, the optimal solutions can be given by solving reaction equations (A4).

$$\begin{cases} \frac{t+p_1^{GG}-2p_2^{GG}+e^2\mu_2}{2t} = 0 \\ \frac{t-2p_1^{GG}+p_2^{GG}+e^2\mu_1}{2t} = 0 \end{cases} \tag{A4}$$

The proofs of optimal solutions are completed.

Appendix B. Proofs of evolutionary game analysis of TOs

B.1. Simplification $F(x)$

From Table 2, we can get excepted profits of TO 1 adopting strategy G or T and the average revenue of TO 1 as follows:

$$\begin{cases} E_1^x = y\pi_1^{GG} + (1-y)\pi_1^{GT} \\ E_1^{1-x} = y\pi_1^{TG} + (1-y)\pi^{TT} \\ \overline{E}_1 = xE_1^x + (1-x)E_1^{1-x} \end{cases} \tag{B1}$$

According to Equation (3) and Equation (B1), we can obtain the replicator dynamic equation for the population of TO 1 shown in the following Equation (B2).

$$\begin{aligned} F(x)=\frac{dx}{dt}&=x(E_1^x-\overline{E}_1)=x[E_1^x-xE_1^x-(1-x)E_1^{1-x}]=x(1-x)(E_1^x-E_1^{1-x}) \\ &=x(1-x)[y\pi_1^{GG}+(1-y)\pi_1^{GT}-y\pi_1^{TG}-(1-y)\pi^{TT}] \\ &=x(1-x)\{(\pi_1^{GG}+\pi^{TT}-\pi_1^{GT}-\pi_1^{TG})y+\pi_1^{GT}-\pi^{TT}\} \end{aligned} \tag{B2}$$

The simplification process of $F(y)$ is similar to the $F(x)$.

B.2. Corresponding evolutionary stability conditions of Proposition 4

According to Equation (7), we can obtain Table B1, which demonstrate the stability of local equilibrium points of TOs under different conditions.

Table B1. The stability of each local equilibrium points under $e\mu_1 < k < e\mu_2$.

	$DetJ$	Sign	TrJ	Sign	Local stability
(0,0)	$\Delta n \cdot \Delta\overline{n}$	$-$	$\Delta n + \Delta\overline{n}$	$\pm$	Saddle point
(0,1)	$-\Delta L \cdot \Delta\overline{n}$	$+$	$\Delta L - \Delta\overline{n}$	$+$	Unstable
(1,0)	$-\Delta\overline{L} \cdot \Delta n$	$+$	$\Delta\overline{L} - \Delta n$	$-$	ESS
(1,1)	$\Delta L \cdot \Delta\overline{L}$	$-$	$-(\Delta L + \Delta\overline{L})$	$-$	Saddle point

Table B2. The stability of each local equilibrium points under $e\mu_2 < k < \frac{e^2\mu_1+3t}{e}$.

	$DetJ$	Sign	TrJ	Sign	Local stability
(0,0)	$\Delta n \cdot \Delta\overline{n}$	$+$	$\Delta n + \Delta\overline{n}$	$+$	Unstable
(0,1)	$-\Delta L \cdot \Delta\overline{n}$	$-$	$\Delta L - \Delta\overline{n}$	$\pm$	Saddle point
(1,0)	$-\Delta\overline{L} \cdot \Delta n$	$-$	$\Delta\overline{L} - \Delta n$	$\pm$	Saddle point
(1,1)	$\Delta L \cdot \Delta\overline{L}$	$+$	$-(\Delta L + \Delta\overline{L})$	$-$	ESS

Appendix C. Proofs for ESS of TOs with government subsidy

C.1. Simplification $F(x)_s$

According to Table 4, we can obtain excepted profits of TO 1 adopting different strategies and the average revenue of TO 1 with government subsidy as follows:

$$\begin{cases} E_{s1}^{x} = y(\pi_1^{GG} + s) + (1-y)(\pi_1^{GT} + s) \\ E_{s1}^{1-x} = y\pi_1^{TG} + (1-y)\pi^{TT} \\ \overline{E}_{s1} = xE_{s1}^{x} + (1-x)E_{s1}^{1-x} \end{cases} \tag{C1}$$

From Equation (3) and Equation (C1), the replicator dynamic equation for the population of TO 1 with government subsidy is obtained and shown in the following Equation (C2).

$$\begin{aligned} F(x)_s &= \frac{dx}{dt} = x(E_1^x - \overline{E}_1) = x[E_1^x - xE_1^x - (1-x)E_1^{1-x}] = x(1-x)(E_1^x - E_1^{1-x}) \\ &= x(1-x)[y(\pi_1^{GG}+s) + (1-y)(\pi_1^{GT}+s) - y\pi_1^{TG} - (1-y)\pi^{TT}] \\ &= x(1-x)\{(\pi_1^{GG} + \pi^{TT} - \pi_1^{GT} - \pi_1^{TG})x + \pi_1^{GT} + s - \pi^{TT}\} \end{aligned} \tag{C2}$$

The simplification process of $F(y)_s$ is similar to that of $F(x)_s$.

The Equation (C3) and (C4) give the Jacobi matrix J_s and the corresponding TrJ_s and $DetJ_s$.

$$J_s = \begin{bmatrix} \frac{\partial F(x)_s}{\partial x} & \frac{\partial F(x)_s}{\partial y} \\ \frac{\partial F(y)_s}{\partial x} & \frac{\partial F(y)_s}{\partial y} \end{bmatrix} = \begin{bmatrix} (1-2x)(\Delta my + \Delta n + s) & x(1-x)\Delta m \\ y(1-y)\Delta\overline{m} & (1-2y)(\Delta\overline{m}x + \Delta\overline{n} + s) \end{bmatrix} \tag{C3}$$

$$\begin{cases} TrJ_s = (1-2x)(\Delta my + \Delta n + s) + (1-2y)(\Delta\overline{m}x + \Delta\overline{n} + s) \\ DetJ_s = (1-2x)(\Delta my + \Delta n + s)(1-2y)(\Delta\overline{m}x + \Delta\overline{n} + s) \\ \qquad\qquad - x(1-x)\Delta my(1-y)\Delta\overline{m} \end{cases} \tag{C4}$$

C.2. Corresponding evolutionary stability conditions of Proposition 5

Under the precondition $\frac{e^2\mu_2 - 3t}{e} < k < e\mu_1$ and $e\mu_1 < k < e\mu_2$, we can obtain Tables C1-C2 from Equation (9), which show the local stability of TOs under different government subsidy.

Table C1. The stability of each local equilibrium points under $s > -\Delta\overline{L}$ and $\frac{e^2\mu_2 - 3t}{e} < k < e\mu_1$.

	$DetJ$	Sign	TrJ	Sign	Local stability
(0,0)	$(\Delta n + s)\cdot(\Delta\overline{n} + s)$	$+$	$\Delta n + \Delta\overline{n} + 2s$	$+$	Unstable
(0,1)	$-(\Delta L + s)\cdot(\Delta\overline{n} + s)$	$-$	$\Delta L - \Delta\overline{n}$	$\pm$	Saddle point
(1,0)	$-(\Delta\overline{L} + s)\cdot(\Delta n + s)$	$-$	$\Delta\overline{L} - \Delta n$	$\pm$	Saddle point
(1,1)	$(\Delta L + s)\cdot(\Delta\overline{L} + s)$	$+$	$-(\Delta L + \Delta\overline{L} + 2s)$	$-$	ESS

Table C2. The stability of each local equilibrium points under $s > -\Delta\overline{L}$ and $e\mu_1 < k < e\mu_2$.

	$DetJ$	Sign	TrJ	Sign	Local stability
(0,0)	$(\Delta n + s) \cdot (\Delta\overline{n} + s)$	$+$	$\Delta n + \Delta\overline{n} + 2s$	$+$	Unstable
(0,1)	$-(\Delta L + s) \cdot (\Delta\overline{n} + s)$	$-$	$\Delta L - \Delta\overline{n}$	$\pm$	Saddle point
(1,0)	$-(\Delta\overline{L} + s) \cdot (\Delta n + s)$	$-$	$\Delta\overline{L} - \Delta n$	$\pm$	Saddle point
(1,1)	$(\Delta L + s) \cdot (\Delta\overline{L} + s)$	$+$	$-(\Delta L + \Delta\overline{L} + 2s)$	$-$	ESS