A Comparative Study of Tourism Supply Chains with Quantity Competition

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Abstract

This paper studies the impact of the involvement of tour operators in a tourism supply chain with multiple hotels and travel agencies. Tour operators negotiate with upstream hotels on the quantity of hotel rooms and promote the accommodation to downstream travel agencies. Two types of game models are formulated to analyze quantity competition in tourism supply chains with and without a tour operator. We conduct a comparative study of the two cases and explore the effects of various parameters. The results show that when the market size of travel agencies is lower than a certain level, then both travel agencies and hotels benefit more from the presence of a tour operator in a tourism supply chain. Furthermore, in this situation, the fluctuations in the profits of both travel agencies and hotels are more violent as the supply chain's membership changes.

Keywords: Tourism supply chain, Hotel accommodation, Tour operator, Travel agency, Game theory.

1 Introduction

Distribution is one of the most critical factors for the competitiveness of tourism organizations and destinations (Buhalis 2000). Setting appropriate distribution channels has a profound influence on customer behavior and on the competitiveness and profitability of the enterprises involved (Buhalis and Laws 2001). Tourism distribution channels vary according to the type of products and markets. For example, during the last two decades of the twentieth century, vertical and horizontal integration occurred in travel distribution. This integration maximizes retention of profits within the group and allows more rapid access to information on the market.

In recent years, the application of supply chain management in tourism has attracted growing attention because its importance has been belatedly recognized by researchers. A tourism supply chain (TSC), as a distribution system, not only focuses on the distribution of tourism products to tourists but also concerns collaboration and competition issues within the enterprises in the system (Yang *et al*. 2009). A typical TSC, as illustrated by Tapper and Font (2008), involves the suppliers of all tourism goods and services that are delivered to the end consumers – the tourists (Fig. 1). Generally speaking, a TSC includes the tourists as end customers. Midstream enterprises provide tourist facilities such as hotels, restaurants, transportation, and shopping facilities. Upstream businesses provide raw materials and services to the midstream enterprises. Either travel agents or tour operators, which provide tourist products or services to tourists, or both, can be involved in the downstream of a TSC. They have a direct or indirect influence on the volume of tourist flows, the choice of destination, and the usage of tourist facilities (Budeanu

2005; Tapper and Font 2008). The purpose of this research is to provide a theoretical analysis of the competitiveness and profitability of enterprises under different supply chain distribution systems.

[Insert Fig. 1 here]

Quantity competition is best described as competition in which enterprises commit to the quantity of the products that they will sell (Sheshinski 1976). Excessive quantity competition among the suppliers of certain products, such as air travel, may lead to the formation of alliances or even collusion over prices (Dixit 1979). In this paper, we consider quantity competition within two TSC distribution systems, both of which contain multiple hotels and travel agencies. The performance of the two types of supply chains is examined through two cases. In the first case, the TSC has a single tour operator; in the second, it has no tour operator. Through this theoretical research, questions such as “What are the optimal room quantities and pricing decisions?” and “What are the maximal profits of the enterprises in the two supply chains?” can be answered. Furthermore, we are more interested in knowing the following questions: 1) In which supply chain do enterprises benefit more with different market sizes? and 2) How are the market equilibriums (quantity, pricing, profit) of the two TSCs influenced by factors such as operating costs and supply chain membership?

Game theory is a powerful tool for analyzing conflict situations involving multiple agents (Cachon and Netessine 2004). The equilibriums of games allow tourism enterprise to predict the behavior of its opponents and react with optimal strategies (Netessine and Shumsky 2005). In this paper, game theory is employed to study optimal quantity decisions and profits of the two TSCs. Thus, we examine two game frameworks. The first one studies a three-level channel in which hotels and travel agencies first play non-cooperative simultaneous quantity competition games (i.e., Cournot games) among themselves and then together engage with the tour operator in a sequential game. In the second case, hotels and travel agencies first play Cournot games, followed by a sequential game to coordinate the room quantity decisions between players. A comparative study is then conducted based on these two cases.

The contribution of this paper is three-fold. First, this is the first attempt in modeling the multi-level TSCs through examining the different TSC distribution systems. Secondly, the game-theoretic approach is used to predict the behavior of tourism enterprises in different TSCs. The application of the models is demonstrated with numerical examples. Thirdly, this study demonstrates that when the market size is below a certain level, both the travel agencies and hotels benefit from a TSC that contains a tour operator. However, under this situation, the profits of both the travel agencies and hotels fluctuate significantly as the membership of travel agency or hotel sector changes. The opposite is true when the market size is above this level. These contributions are useful for tourism business decision-makings when a multi-level TSCs contains travel agencies, hotels and tour operators.

The remainder of this paper is organized as follows. Section 2 reviews the essential literature on TSCs and game theory. The subsequent section describes the two TSCs problems and devises the game models and solutions. The impacts of the different supply chains and the various parameters of the models are analyzed in Section 4. The last section concludes the study and recommends some directions for future research.

2 Literature Review

This study relates to two main subject areas: TSC management and the application of game theory to TSC management.

In general, the literature on TSC management is very limited. Some studies have focused on the relationships between tour operators and accommodation providers. Buhalis (2000) and Medina-Muñoz *et al.* (2003) examined the competitive and cooperative relationships among tour operators and hotels in a distribution channel. Theuvsen (2004) showed that coordination among enterprises could benefit the tourism industry. However, this research focused only on the cooperative and competitive relationships between the two sectors and ignored the other players in a TSC. The interactions among different supply chains have also not been investigated. Zhang *et al.* (2009) systematically reviewed the literature on current tourism studies from the TSC perspective and developed a framework for TSC management research.

Game theory has been extensively used in manufacturing supply chains to study the competitive and cooperative relationships among firms. Choi (1991, 1996) investigated a pricing competition problem for a channel structure consisting of two competing manufacturers and one common retailer that sells both manufacturers' products. Minakshi (1998) analyzed a three-channel structure with two competing manufacturers and two retailers to examine the channel competition problem. Huang *et al.* (2011) studied supplier selection, pricing, and inventory coordination problems using a dynamic game model. In recent years, game theory has begun to be applied to examine competition and cooperation issues in the tourism industry. Aguiló *et al.* (2002) considered an oligopolic tourism market in which tour operators have the market power to determine their price level and market share. Wie (2005) employed an N-person, non-zero sum, non-cooperative dynamic game to study strategic capacity investment in the cruise line industry. Candela and Cellini (2006) suggested using differentiated oligopoly models to examine tourism development strategies. García and Tugores (2006) employed a vertical differentiation duopoly model to rationalize the coexistence of high- and low-tariff hotels. Yang *et al*. (2009) investigated the cooperation and competition between different TSCs through non-cooperative games. Huang *et al*. (2010) studied the competitive and cooperative relationships among the enterprises in a TSC covering package holidays under quantity competition. However, all of these studies focused on only a single level or, at most, two levels of a TSC. In this respect, our study is the first to use the game theory approach to study the coordination and competition relationships of a multi-level TSC.

3 Research Method

We consider two different TSCs for distributing the accommodation provided by several hotels. The travel agencies (TAs) sell the accommodation to tourists as part of their tourism products. In the first TSC, a tour operator (TO) is included (known as the WTO case); in the second one, there is no TO in the TSC (known as the NTO case). The two cases are shown in Fig. 2. In the first case, the hotels (HOs) are assumed to negotiate the number of rooms available to tourists among themselves and then collectively negotiate with the TO. The TO then negotiates and sells the hotel rooms to the TAs. In the second case, the HOs negotiate the number of available rooms among themselves and sell them through the TAs directly. We assume that the accommodation sector is an oligopoly and hence has a dominant power over the TO and TAs in both TSCs; for example, the hotels in Sanya, a noted tourist resort in China, mark up their room rates in holidays conformably and then promote these to the markets. This assumption was also employed by Huang *et al.* (2010). We will examine the behavior (room quantity decisions and profits) of the enterprises under different TCSs.

[Insert Fig. 2 here]

We assume that there are N TAs and M HOs. The parameters and variables for the TA, TO, and HO are provided in Table 1. All of the TAs are assumed to supply the same type of accommodation to the same target market. The enterprises optimize their room quantity decisions to maximize their individual profits. HOs sell hotel rooms to TOs and TAs purchase hotel rooms from TOs, and thus $Q^{(\cdot)} = \sum_{j=1}^{N} q_o^{j(\cdot)} = \sum_{i=1}^{M} q_a^{i(\cdot)} = q_g$. We assume that the entrance of a

TO into the TSC brings down the operating costs for the HOs and TAs; that is, $c_o^j > c_o^{j`}$ and $c_a^i > c_a^{i`}$.

[Insert Table 1 here]

Three sectors or levels are included in the TSC with a TO or WTO case: the HO, TO, and TA sectors. For the TA and HO sectors, there is internal competition among the multiple enterprises in the sector. At the same time, the TA, TO, and HO sectors compete with one another to provide accommodation to maximize their profits. In the TSC without a TO or NTO case, two sectors are included: the HO and TA sectors. Here, TAs purchase accommodation to meet their demand directly from the HOs. Due to the presence of multiple enterprises within the TA and HO sectors, there is internal competition as well. The TAs and HOs also compete with each other to provide accommodation for tourists. HOs are assumed to be more aggressive than the other suppliers in the TSC due to their oligopolistic power, and thus they enjoy a so-called first-mover advantage.

We employ game models to study the quantity decisions in the two TSCs with competition and coordination. A normal game is composed of three components: players, the strategies available to each player, and the payoffs received by each player (Cachon and Netessine 2004). In our model, all of the enterprises (HOs, the TO, and TAs) are game players. Profits are their payoffs, and these are determined by their corresponding quantity strategies.

In this paper, two game models are formulated for the two cases. In the first WTO case, this sequential game is composed of two Stackelberg games. The Stackelberg game is a leader-follower game in which the leader firm moves first and then the follower firm moves sequentially (Başar 1986). Specifically, the follower reacts to the leader’s decisions and the leader takes the follower's reactions into consideration in its respective decision making (Choi 1991). The first Stackelberg game is between the TO and HOs; in this game, the HOs make their first move on quantity decisions using the TO's reaction function and the TO determines its quantity decision based on the HOs' quantity decisions. The second Stackelberg game is between the TAs and the TO; in this game, the TO chooses its quantity decision using the reaction functions of the TAs and the TAs determine their quantity decisions based on the TO's quantity decision. The game rules are shown in Fig. 3(a). In the second NTO case, only the TA and HO sectors play a sequential game or a Stackelberg game; the HOs also take the leadership in these games. The game rules are presented in Fig. 3(b).

[Insert Fig. 3 here]

We assume a linear inverse demand function for TA^j under quantity competition as this is commonly used in the game theory approach (Carr and Karmarkar 2005; Huang *et al*. 2010):

$$p_o^{j(\cdot)} = \alpha - \beta q_o^{j(\cdot)} - \gamma \sum_{i \neq j}^{N} q_o^{i(\cdot)} , \tag{1}$$

where α is the market size parameter and γ / β captures the degree of substitution of the various hotels. If $\gamma = 0$, then the hotels are independent, whereas $\beta = \gamma$ indicates a perfect substitution between the hotels.

In the WTO case, the profit function of TA^j is

$$\pi_o^j = q_o^j \left(p_o^j - p_g - c_o^j \right). \tag{2}$$

In the NTO case, the TAs directly purchase tourism products from HOs, so the profit function of TA^j is

$$\pi_o^{j'} = q_o^{j'}\left(p_o^{j'} - p_a' - c_o^{j'}\right). \tag{3}$$

The profit for TO in the WTO case is

$$\pi_g = Q\left(p_g - p_a - c_g\right). \tag{4}$$

The profit for HO^i in both cases is

$$\pi_a^{i(')} = q_a^{i(')}\left(p_a^{(')} - c_a^{(')}\right). \tag{5}$$

Backward induction is used to solve the sequential games in the two cases. The last stage of each game allows the TAs to decide the room quantities simultaneously in a competitive environment. Then, the TO makes the quantity decision, if needed, based on the reactions of the TAs. Lastly, the HOs simultaneously decide on the quantity decisions based on the TAs' reactions in the NTO case and the TO's reactions in the WTO case. The quantity and pricing decisions and the profits for all enterprises are shown in Table 2. The detailed derivation is given in Appendix A.

Summing up the equations for all of the TAs in the TSCs, the total room demands in the two different TSCs are:

$$Q = \frac{MN\left(\alpha - \overline{c_o} - c_g - c_a\right)}{2\left(M+1\right)\left(2\beta + \gamma\left(N-1\right)\right)} \tag{6}$$

$$Q' = \frac{MN\left(\alpha - \overline{c_o}' - c_a'\right)}{\left(M+1\right)\left(2\beta + \gamma\left(N-1\right)\right)} \tag{7}$$

From equations (6) and (7), we can obtain the total number of rooms sold. We can see that the equilibrium total quantities of the two TSCs are increasing functions of market size and a decreasing function of unit cost and degree of substitution of the hotels. The profits of HOs, the

TO, and TAs are also influenced by the market size, operating cost, and the degree of hotel substitution in the same way as the total quantities are (see Table 2).

[Insert Table 2 here]

4 Findings and Implications

In this section, we consider the impacts of different TSCs on the quantities decisions and profits of the enterprises. We mainly discuss the implications of the results reported in the previous section. First, the effects of the operating cost and TSC membership are analyzed. Then, comparative studies between the WTO and NTO cases are conducted. Several interesting results are presented from the theoretical analysis.

4.1 Effects of parameters

We first investigate the effects of various parameters on both TSCs. These parameters include the operating cost and TSC membership, which are the commonly studied parameters in TSC management research (Choi 1991, 1996; Minakshi 1998; Huang *et al*. 2010).

Proposition 1. 1) A decrease in one enterprise's operating cost reduces the room rates or service charges of its downstream enterprises but raises the room rates or service charges of its upstream enterprises. 2) Such a decrease improves the profits of the enterprises in the other sectors but decreases the profits of the enterprises in the corresponding sector.

Proof. See Appendix B.

With the decrease in the operating cost, the tourists could be offered a lower room rate, thus increasing the consumer surplus. Proposition 1 has two implications. First, as the operating cost of one enterprise decreases, the other enterprises would not all increase or decrease their room rates or service charges. The room rates or service charges of its upstream enterprises increase while those of its downstream enterprises reduce irrespective of the TSC employed to distribute the tourism products. Second, the decrease in the operating cost could improve the profits of enterprises in the other sectors regardless of the TSC employed. However, the profits of the enterprises in the same sector might not be increased due to the switch of the tourists. More specifically, a decrease in an HO's operating cost reduces the room rates of the TAs and the TO (if any) and increases their profits. A decrease in the TO's operating cost (if any) increases the HOs' room rates and reduces the TAs' service charges, but increases their profits. A decrease in the TAs' operating costs increases the HOs' room rates and the TO's service charge (if any) along with their profits. The example in Table 3 gives an intuitive illustration of the findings. The figures in this table are value changed, compared with the benchmarks listed, when there is a decrease in operating cost and the market size varies.

[Insert Table 3 here]

From Table 3, we observe that regardless of the TSC employed, the decrease in one enterprise's operating cost reduces the room rates or service charges of the downstream enterprises but increases those of the upstream enterprises. For example, when the operating cost of the TO in the WTO case decreases by 15, the downstream TAs all reduce their prices by 1.04 but the upstream HOs' prices increase by 2.50. All of the enterprises increase their profits except for those in the same sector. This can be seen from the decrease in the operating cost of the TA. When the operating cost of one TA decreases by 15, the profits of the enterprises in other sectors increase, but the other TAs in the same sector are not, their profits decreased by 6.24. Another important observation is that the market size does not influence the change in room rate and service charge when the operating cost changes, but the more significant influence of larger market size on the profit changes as the operating cost changes. For example, in the WTO case, when the market size is 500 and the operating cost of one TA decreases by 15, its profit increases by 469.80 and the other TAs' profits decrease by 6.24; when market size increases to 600, the values are 643.80 and 8.55, respectively.

The number of members in a TSC determines the competition intensity (Yang *et al*. 2009). Based on the foregoing observations, we obtain the following proposition.

Proposition 2. 1) An increase in membership in the TA or HO sector would not change the room rates or service charges of the upstream enterprises but could reduce the room rates or service charges of the enterprises in the corresponding sector as well as those of the downstream enterprises. 2) Such an increase benefits the enterprises in other sectors but negatively affects the profits of the enterprises in the corresponding sector.

Proof. See Appendix B.

An increase in the number of tourism enterprises leads to intensive competition (Banker *et al*. 1998), and intensive competition brings the price of tourism products down (Choi 1991). Proposition 2 shows that increasing membership in one sector can provide the downstream enterprises with a lower room rate or service charge, thus attracting more tourists. However, the upstream enterprises would not reduce their charges. Hence, all of the enterprises in the other sectors could benefit from at least one of the two factors: lower prices and greater demand (tourists). The enterprises in the corresponding sector cannot increase their profits due to the incumbent firms within the sector. Table 4 illustrates our findings.

[Insert Table 4 here]

From Table 4, we can see that regardless of the market size and the TSC, as the membership of the TA sector increases, the upstream enterprises do not change their pricing decisions.

However, as can be seen from the increase in the HO sector's membership, the downstream enterprises do reduce their pricing decisions. For example, when the HO sector increases by one member and the market size is 500 in the WTO case, the room rates or service charges of the TO and TAs reduce by 3.75 and 4.51 respectively. Due to the severe competition when membership in one sector increases, the enterprises in other sectors benefit from the competition. For example, in the WTO case, when the market size is 600, with an increase in the HO sector's membership, the profits of the TO and the TA increase by 16637.15 and 5.86 respectively while those of each original HO decrease by 158.45. Most interestingly, we also observe that the change in enterprises' profits and total room demand are more significant in the NTO case when the membership of the TA or HO sector increases. For example, when the market size is 500 and the TA sector increases by one member, the profit of the other TA in the WTO case decreases by 9.77, while in the NTO case, this profit decreases by 45.09. For each HO in the WTO case, profit increases by 7.03, but in the NTO case, the profit increases by 21.01. In the following sections, we will see that this difference is closely related to market size and operating costs.

4.2 Comparison of the WTO and NTO cases

From the above analysis, we know the common features of the two different TSCs. To understand the interaction among the different supply chains, we have to compare the equilibrium quantities and profits in the two different supply chains. For convenience, we denote $\Delta c_o = \overline{c_o}' - \overline{c_o}$, $\Delta c_o^j = c_o^j{}' - c_o^j$, $\Delta c_a = c_a' - c_a$ and $\Delta_1 = -\alpha + c_a' + \overline{c_o}' + \Delta c_a + \Delta c_o - c_g$,

$\Delta_2 = (\sqrt{2}-1)(-\alpha + c_a' + \overline{c_o}') + \Delta c_a + \Delta c_o - c_g$. Since $\alpha > c_a' + \overline{c_o}'$, we have $\Delta_2 > \Delta_1$. Throughout our analysis, the following proposition is relevant.

Proposition 3. The following relationships exist between the WTO and NTO cases: 1) The profit of the TO (if any) is positive. 2) If $\Delta_1 > 0$, total room demand, TAs' profits, and HOs' profits in the WTO case are all higher than in the NTO case. So, $Q > Q`$, $\pi_o^j > \pi_o^j`$, $\pi_a > \pi_a`$. 3) If $\Delta_2 > 0 > \Delta_1$, total room demand and each TA's profit in the WTO case are lower than in the NTO case, but the opposite is the case for the HOs' profits. So, $Q < Q`$, $\pi_o^j < \pi_o^j`$, $\pi_a > \pi_a`$. 4). If $\Delta_2 < 0$, total room demand, TAs' profits, and HOs' profits in the WTO case are all lower than in the NTO case. So, $Q < Q`$, $\pi_o^j < \pi_o^j`$, $\pi_a < \pi_a`$.

Proof. See Appendix B.

Proposition 3 provides us with several observations. The first one, which is intuitive, is that the TO benefits from being involved in the TSC. Second, the relationship between the two TSCs in terms of total room demand and the TAs' and HOs' profits depends on the operating cost and the market size. In this proposition, Δ_1 and Δ_2 are defined by operating cost and market size and used as the judgment for the comparison of the two TSCs. Third, through simple transformation, the judgments that employed Δ_1 and Δ_2 (e.g., $\Delta_1 > 0$) can be transformed to the relationship between market size and operating cost. More specifically, when $\Delta_1 > 0$ or the market size α is smaller than a certain level ($\alpha < c_a` + \overline{c_o}` + \Delta c_a + \Delta c_o - c_g$), both TAs and HOs benefit more in the WTO case. In this situation, TAs and HOs have no incentive to be involved in the TSC without a TO. When the market size satisfies $\Delta_2 > 0 > \Delta_1$ or $\alpha > c_a` + \overline{c_o}` + \Delta c_a + \Delta c_o - c_g$ and $\alpha < c_a` + \overline{c_o}` + \left(\Delta c_a + \Delta c_o - c_g\right) / \left(\sqrt{2} - 1\right)$, the total rooms sold and the TAs' profits are lower in the WTO case than in the NTO case. The opposite is the case with regard to the HOs' profits. Hence, there is no incentive for TAs to get involved in the WTO case, but there is for the HOs. When the market size satisfies $\Delta_2 < 0$ or $\alpha > c_a` + \overline{c_o}` + \left(\Delta c_a + \Delta c_o - c_g\right)/\left(\sqrt{2} - 1\right)$, the TAs and HOs have no incentive to use the TO as the medium to sell their rooms. In this circumstance, there is no need for the TAs to purchase hotel rooms from the TO as they already have sufficient bargaining power due to the larger market. The HOs also enjoy higher profits by selling their accommodation directly to the TAs. In our example above, we can see that the market size and operating cost satisfy $\Delta_2 < 0$. Thus, the total rooms sold, the TAs' profits, and the HOs' profits in the WTO case are worse than they are in the NTO case (see Table 5).

[Insert Table 5 here]

4.3 Comparison of the effects of the various parameters on the WTO and NTO cases

We are interested in comparing the impacts of the various parameters on the WTO and NTO cases. In both cases, the operating costs of the two TSCs are different, and so it would be meaningless to compare the effects of these parameters. Rather, we compare only the effects of parameters that have common values in both cases, such as the number of members in the TSC. In Proposition 2, we considered the impact of membership of the HO and TA sectors on both TSCs. The following proposition further summarizes the differences in the impacts of this parameter on the TSCs.

Proposition 4. The following relationships exist: 1) If $\Delta_1 > 0$, the impacts of the change in the membership of the HO or TA sector on total room demand and HOs' and TAs' profits are more significant in the WTO case. That is, $\left|\frac{\partial Q}{\partial X}\right| > \left|\frac{\partial Q`}{\partial X}\right|$, $\left|\frac{\partial \pi_o^j}{\partial X}\right| > \left|\frac{\partial \pi_o^{j}`}{\partial X}\right|$, $\left|\frac{\partial \pi_a^j}{\partial X}\right| > \left|\frac{\partial \pi_a^{j}`}{\partial X}\right|$. 2) If $\Delta_2 > 0 > \Delta_1$, the impacts of the change in the membership of the HO or TA sector on total room demand and TAs' profit in the WTO case are less than they are in the NTO case, but the opposite is true in the case of HOs' profits. That is, $\left|\frac{\partial Q}{\partial X}\right| < \left|\frac{\partial Q'}{\partial X}\right|$, $\left|\frac{\partial \pi_o^j}{\partial X}\right| < \left|\frac{\partial \pi_o^{j\,\prime}}{\partial X}\right|$, $\left|\frac{\partial \pi_a^j}{\partial X}\right| > \left|\frac{\partial \pi_a^{j\,\prime}}{\partial X}\right|$. 3) If $\Delta_2 < 0$, the impacts of the change in the membership of the HO or TA sector on total room quantity and the HOs' and TAs' profits are less significant in the WTO case. That is, $\left|\frac{\partial Q}{\partial X}\right| < \left|\frac{\partial Q'}{\partial X}\right|$,

$\left|\frac{\partial \pi_o^j}{\partial X}\right| < \left|\frac{\partial \pi_o^{j\,\prime}}{\partial X}\right|$, $\left|\frac{\partial \pi_a^j}{\partial X}\right| < \left|\frac{\partial \pi_a^{j\,\prime}}{\partial X}\right|$. ($X = M, N$).

Proof. See Appendix B.

Proposition 4 indicates that the change of the membership in TA sector has the same level of influence as the change of the membership in HO sector on total room demand, HOs' profit, and TAs' profit. The difference is that the impacts are either negative or positive. This is due to the fact that, according to Proposition 2, an increase in the membership of one sector increases the profits of the enterprises in other sectors but decreases the profits of the enterprises in its own sector. For example, if $\Delta_1 > 0$ or the market size satisfies $\alpha < c_a' + \overline{c_o}' + \Delta c_a + \Delta c_o - c_g$, a change in the membership of the TA sector or the HO sector has a more significant impact on the total quantity of rooms to sell and the HOs' and the TAs' profits in the WTO case. However, if the TA sector's membership increases/decreases, the total room quantity and the HOs' profits increase/decrease more significantly, while the TAs' profits decrease/increase more significantly, in the WTO case. If the membership of the HO sector increases/decreases, the total room quantity and the TAs' profits increase/decrease more significantly, but the HOs' profits decrease/increase more significantly, in the WTO case.

Proposition 4 tells us that when the TO’s market size satisfies $\alpha < c_a + \overline{c_o} + \Delta c_a + \Delta c_o - c_g$, the total room quantity and the profits of HOs and TAs are more sensitive to changes in the membership of TAs or HOs in the WTO case. When the market size satisfies $\alpha > c_a + \overline{c_o} + \left(\Delta c_a + \Delta c_o - c_g\right)/\left(\sqrt{2}-1\right)$, the reverse is true. When the TO’s market size satisfies $\alpha > c_a + \overline{c_o} + \Delta c_a + \Delta c_o - c_g$ and $\alpha < c_a + \overline{c_o} + \left(\Delta c_a + \Delta c_o - c_g\right)/\left(\sqrt{2}-1\right)$, total room quantity and the TAs’ profits are more sensitive to changes in the membership of TAs or HOs in the NTO case, but the HOs’ profits are opposite. In the numerical example of Proposition 2 (Table 4), the changes in enterprises’ profits and total room demand are more significant in the NTO case when membership of the TA or HO sector increases; this is because the market size and operating costs satisfy the relationship $\Delta_2 < 0$.

Taking Proposition 3 into consideration, when $\Delta_1 > 0$, although it would be more profitable for TAs and HOs to deliver their products through a TO, the fluctuations in the profits of both TAs and HOs are more violent in the WTO case as membership of the TA or HO sector changes. When $\Delta_2 < 0$, it would be more profitable for TAs and HOs to deliver their products without a TO. However, in this situation, the profits of both TAs and HOs fluctuate more violently as membership of the TA or HO sector changes.

5 Conclusion

In this paper, we have studied two TSCs, both with multiple HOs and TAs, that offer tourists the same type of accommodation. For comparison, we investigated the interactions between two supply chains, one with and the other without a TO. Cournot game and sequential game models were formulated to analyze the optimal quantity decisions for each enterprise in the two channels. A comparative study of the two cases was conducted and the impacts of parameters such as operating costs and the membership of TSC were explored.

Several useful and important managerial implications arise from the findings, and these can be summarized as follows. First, when the operating cost of one enterprise in a TSC decreases, the downstream enterprises will reduce their room rates or service charges, which leads to increased profits. The upstream enterprises will increase room rates or service charges and thus also achieved improved profits. Our results also show that when the market size is lower than a certain level or satisfies the relationship ($\alpha < c_a' + \overline{c_o}' + \Delta c_a + \Delta c_o - c_g$), both the TAs and the HOs achieve higher profits in a TSC that includes a TO compared to a TSC without a TO. However, in this situation, fluctuations in the profits of both TAs and HOs are more violent as the membership of the TA or HO sector changes. The opposite is true when the market size satisfies the relationship ($\alpha > c_a' + \overline{c_o}' + \left(\Delta c_a + \Delta c_o - c_g\right) / \left(\sqrt{2} - 1\right)$).

Although its findings contribute to our understanding of the impacts of various parameters on the gains and losses of TSCs with and without a TO, this study suffers from several limitations. First, the model concerns only a single TO. A more general model with multiple TOs would better reflect the real competitive environment of the travel industry. Second, a wider range of distribution channels could be introduced. For example, a situation in which the HOs sell their rooms to TOs and TAs simultaneously could be studied to generate interesting and relevant findings. Third, we consider only one strategic variable – the quantity variable (which is measured either by the number of tourists or the number of hotel rooms). A favorable direction for future research would be to include other strategic variables, such as pricing and service quality. The fourth limitation of the study is that we assume that individual enterprises in the same sector have the same status. However, some HOs and TOs have more market power than others. The final limitation of the study is that we assume that the hotel market in the destination is an oligopoly, with hotels enjoying first-mover advantage. In more mature destinations, however, it tends to be the TOs or TAs that possess the market power and enjoy the first-mover advantage, and thus other types of sequential games could be considered.

Appendix A.

For the WTO case, to optimize the profit, we first solve the first order condition of Eq. (2)

$d\pi_o^j / dq_o^j = 0$.

So, TA^j determines the room quantity as

$$q_o^j = \frac{\alpha - c_o^j - p_g}{2\beta} - \frac{\gamma}{2\beta}\sum_{i \neq j}^{N} q_o^i \tag{A.1}$$

From Eq. (A.1), we obtain

$$\begin{bmatrix} 2\beta & \gamma & \dots & \gamma \\ \gamma & 2\beta & \dots & \gamma \\ \dots & \dots & \dots & \dots \\ \gamma & \gamma & \dots & 2\beta \end{bmatrix} \begin{bmatrix} q_o^1 \\ q_o^2 \\ \dots \\ q_o^N \end{bmatrix} = \begin{bmatrix} \alpha - c_o^1 - p_g \\ \alpha - c_o^2 - p_g \\ \dots \\ \alpha - c_o^N - p_g \end{bmatrix}. \tag{A.2}$$

We define

$$P = \begin{bmatrix} 2\beta & \gamma & \dots & \gamma \\ \gamma & 2\beta & \dots & \gamma \\ \dots & \dots & \dots & \dots \\ \gamma & \gamma & \dots & 2\beta \end{bmatrix} = (2\beta - \gamma) \begin{bmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 1 \end{bmatrix} + \gamma \begin{bmatrix} 1 & 1 & \dots & 1 \\ 1 & 1 & \dots & 1 \\ \dots & \dots & \dots & \dots \\ 1 & 1 & \dots & 1 \end{bmatrix}. \tag{A.3}$$
$$= (2\beta - \gamma) I_n + \gamma B_n$$

It can then be shown that

$$\left(xI_n + yB_n\right)\left(\frac{1}{x} I_n - \frac{y}{x(x+ny)} B_n\right) = I_n + \frac{y}{x} I_n - \frac{xy}{x(x+ny)B_n} - \frac{ny^2}{x(x+ny)} B_n = I_n .$$

We obtain the inverse of matrix S as follows:

$$P^{-1}=\frac{1}{2\beta-\gamma}\begin{bmatrix}1&0&\dots&0\\0&1&\dots&0\\\dots&\dots&\dots&\dots\\0&0&\dots&1\end{bmatrix}-\frac{\gamma}{(2\beta-\gamma)(2\beta-\gamma+\gamma N)}\begin{bmatrix}1&1&\dots&1\\1&1&\dots&1\\\dots&\dots&\dots&\dots\\1&1&\dots&1\end{bmatrix}, \qquad \text{(A.4)}$$

$$=\begin{bmatrix}a-b&-b&\dots&-b\\-b&a-b&\dots&-b\\\dots&\dots&\dots&\dots\\-b&-b&\dots&a-b\end{bmatrix}$$

where $a=\frac{1}{2\beta-\gamma}, b=\frac{\gamma}{(2\beta-\gamma)(2\beta-\gamma+\gamma N)}$.

Based on Eqs. (A.2) and (A.4), we obtain

$$\begin{bmatrix}q_o^1\\q_o^2\\\dots\\q_o^N\end{bmatrix}=\begin{bmatrix}a-b&-b&\dots&-b\\-b&a-b&\dots&-b\\\dots&\dots&\dots&\dots\\-b&-b&\dots&a-b\end{bmatrix}\begin{bmatrix}\alpha-c_o^1-p_g\\\alpha-c_o^2-p_g\\\dots\\\alpha-c_o^N-p_g\end{bmatrix}.$$

Thus, the equilibrium quantity for TO^j is as follows:

$$q_o^j=\frac{\alpha-c_o^j-p_g}{2\beta-\gamma}-\frac{\gamma N\left(\alpha-c_o^j-p_g\right)}{(2\beta-\gamma)(2\beta-\gamma+\gamma N)}. \qquad \text{(A.5)}$$

Solving the equation leads to the following equilibrium for TA^j:

$$q_o^j=\frac{\alpha-c_o^j-p_g}{2\beta-\gamma}-\frac{\gamma N\left(\alpha-\overline{c_o}-p_g\right)}{(2\beta-\gamma)\left(2\beta+\gamma(N-1)\right)} \qquad \text{(A.6)}$$

where $\overline{c_o}=\frac{1}{N}\sum_{j=1}^{N}c_o^j$.

Thus,

$$Q = \frac{N(\alpha - \overline{c_o} - p_g)}{2\beta + \gamma(N-1)} \tag{A.7}$$

The profit function for the TO is

$$\pi_g = Q(p_g - p_a - c_g) \tag{A.8}$$

From Eq. (A.8), we obtain the optimal price for the TO

$$p_g = \alpha - \overline{c_o} - \frac{Q\left(2\beta + \gamma\left(N-1\right)\right)}{N} \tag{A.9}$$

So, the total rooms in the TSC can be derived by $d\pi_g / dQ = 0$

$$Q = \frac{N\left(\alpha - \overline{c_o} - p_a - c_g\right)}{2\left(2\beta + \gamma\left(N-1\right)\right)} \tag{A.10}$$

From Eq. (5), we obtain the price for each HO^i from the equation:

$$p_a = \alpha - \overline{c_o} - c_g - \frac{2Q\left(2\beta + \gamma\left(N-1\right)\right)}{N} \tag{A.11}$$

The quantity for each HO^i is

$$q_a^i = \frac{N\left(\alpha - \overline{c_o} - c_p - c_a\right)}{4\left(2\beta + \gamma\left(N-1\right)\right)} - \frac{\sum_{k \neq i}^{M} q_a^k}{2} \tag{A.12}$$

A series of *M* independent linear equations has a symmetric solution, so

$$q_a = \frac{N\left(\alpha - \overline{c_o} - c_g - c_a\right)}{2\left(M+1\right)\left(2\beta + \gamma\left(N-1\right)\right)} \tag{A.13}$$

Since $q_a > 0$, we have $\alpha - \overline{c_o} - c_g - c_a > 0$.

For the NTO case, TA^j determines the tourist quantity as

$$q_o^{j`} = \frac{\alpha - c_o^{j`} - p_a`}{2\beta} - \frac{\gamma}{2\beta} \sum_{i \neq j}^{N} q_o^{i`} \tag{A.14}$$

Solving the equation leads to the following, using the same method as in the WTO case:

$$q_o^{j\prime} = \frac{\alpha - c_o^{j\prime} - p_a^{\prime}}{2\beta - \gamma} - \frac{\gamma N\left(\alpha - \overline{c_o}^{\prime} - p_a^{\prime}\right)}{\left(2\beta - \gamma\right)\left(2\beta + \gamma\left(N-1\right)\right)} \tag{A.15}$$

$$Q^{\prime} = \frac{N\left(\alpha - \overline{c_o}^{\prime} - p_a^{\prime}\right)}{2\beta + \gamma\left(N-1\right)} \tag{A.16}$$

The price for each HO is

$$p_a^{\prime} = \alpha - \overline{c_o}^{\prime} - \frac{Q^{\prime}\left(2\beta + \gamma\left(N-1\right)\right)}{N} \tag{A.17}$$

Thus, HO^i defines the tourist quantity as

$$q_a^{i\prime} = \frac{N\left(\alpha - \overline{c_o}^{\prime} - c_a^{\prime}\right)}{2\left(2\beta + \gamma\left(N-1\right)\right)} - \frac{\sum_{k\neq i}^{M} q_a^{k\prime}}{2} \tag{A.18}$$

Each HO determines the tourist quantity as

$$q_a^{\prime} = \frac{N\left(\alpha - \overline{c_o}^{\prime} - c_a^{\prime}\right)}{\left(M+1\right)\left(2\beta + \gamma\left(N-1\right)\right)} \tag{A.19}$$

Since $q_a^{\prime} > 0$, thus, we have $\alpha - \overline{c_o}^{\prime} - c_a^{\prime} > 0$.

Appendix B. Proof of the propositions

Proof of Proposition 1.

Proof. As $q_a = \dfrac{N(\alpha - \overline{c_o} - c_g - c_a)}{2(M+1)[2\beta + \gamma(N-1)]} > 0$, the following derivatives are satisfied.

For parameter c_a :

$$\frac{\partial p_o^j}{\partial c_a} = \frac{M(\beta + \gamma N - \gamma)}{2(2\beta + \gamma N - \gamma)(M+1)} > 0 \,,$$

$$\frac{\partial q_o^j}{\partial c_a} = -\frac{M}{2(2\beta + \gamma N - \gamma)(M+1)} < 0 \,,$$

$$\frac{\partial \pi_o^j}{\partial c_a} = \frac{\partial(\beta q_o^{j2})}{\partial c_g} < 0 \,,$$

$$\frac{\partial p_g}{\partial c_a} = \frac{M}{2(M+1)} > 0 \,,$$

$$\frac{\partial q_g}{\partial c_a} = -\frac{MN}{2(2\beta + \gamma N - \gamma)(M+1)} < 0 \,,$$

$$\frac{\partial \pi_g}{\partial c_a} = -\frac{M^2 N}{(2\beta + \gamma N - \gamma)(M+1)}(\alpha - \overline{c_o} - c_g - c_a) < 0 \,,$$

$$\frac{\partial p_a}{\partial c_a} = \frac{M}{M+1} > 0 \,,$$

$$\frac{\partial q_a}{\partial c_a} = -\frac{N}{2(M+1)(2\beta + \gamma N - \gamma)} < 0 \,,$$

$$\frac{\partial \pi_a}{\partial c_a} = -\frac{N(\alpha - \overline{c_o} - c_g - c_a)}{(M+1)^2(2\beta + \gamma N - \gamma)} < 0 \,,$$

$$\frac{\partial Q}{\partial c_a} = -\frac{MN}{2(2\beta + \gamma N - \gamma)(M+1)} < 0 \,.$$

For parameter c_o^j:

$$\frac{\partial p_o^j}{\partial c_o^j} = \frac{(\beta-\gamma)(M+2)+\gamma NM}{2(2\beta+\gamma N-\gamma)(M+1)N} + \frac{(\beta-\gamma)(4\beta+2\gamma N-\gamma)}{2(2\beta-\gamma)(2\beta+\gamma N-\gamma)} > 0,$$

$$\frac{\partial q_o^j}{\partial c_o^j} = \frac{\beta(-4N(M+1)+2M+4)+\gamma(2N(2-N)(M+1)-M-2)}{2(2\beta-\gamma)(2\beta+\gamma N-\gamma)(M+1)N} < 0,$$

$$\beta \geq \gamma \Rightarrow \beta(-4N(M+1)+2M+4)+\gamma(2N(2-N)(M+1)-M-2) < 0,$$

$$\frac{\partial \pi_o^j}{\partial c_o^j} = 2\beta \frac{\partial q_o^j}{\partial c_o^j} q_o^j < 0,$$

$$\frac{\partial p_o^k}{\partial c_o^j} = \frac{(\beta-\gamma)(M+2)+\gamma MN}{2(2\beta+\gamma N-\gamma)(M+1)} + \frac{\gamma(\beta-\gamma)}{2(2\beta-\gamma)(2\beta+\gamma N-\gamma)} > 0$$

$$\frac{\partial q_o^k}{\partial c_o^j} = \frac{(M+2)(2\beta-\gamma)+2\gamma N(M+1)}{2(2\beta-\gamma)(2\beta+\gamma N-\gamma)(M+1)N} > 0,$$

$$\frac{\partial p_g}{\partial c_o^j} = -\frac{M+2}{2(M+1)N} < 0,$$

$$\frac{\partial Q}{\partial c_o^j} = -\frac{M}{2(2\beta+\gamma N-\gamma)(M+1)} < 0,$$

$$\frac{\partial \pi_g}{\partial c_o^j} = -\frac{M^2(\alpha-\overline{c_o}-c_g-c_a)}{(M+1)(2\beta+\gamma N-\gamma)} < 0,$$

$$\frac{\partial p_a}{\partial c_o^j} = -\frac{1}{(M+1)N} < 0,$$

$$\frac{\partial q_a}{\partial c_o^j} = -\frac{1}{2(M+1)(2\beta+\gamma N-\gamma)} < 0,$$

$$\frac{\partial \pi_a}{\partial c_o^j} = -\frac{\alpha - \overline{c_o} - c_g - c_a}{(M+1)^2(2\beta + \gamma N - \gamma)} < 0 .$$

For parameter c_g :

$$\frac{\partial p_o^j}{\partial c_g} = \frac{M(\beta + \gamma N - \gamma)}{2(2\beta + \gamma N - \gamma)(M+1)} > 0 ,$$

$$\frac{\partial q_o^j}{\partial c_g} = -\frac{M}{2(2\beta + \gamma N - \gamma)(M+1)} < 0 ,$$

$$\frac{\partial \pi_o^j}{\partial c_g} = \frac{\partial(\beta q_o^{j2})}{\partial c_g} < 0 ,$$

$$\frac{\partial p_g}{\partial c_g} = \frac{M}{2(M+1)} > 0 ,$$

$$\frac{\partial Q}{\partial c_g} = -\frac{MN}{2(2\beta + \gamma N - \gamma)(M+1)} < 0 ,$$

$$\frac{\partial \pi_g}{\partial c_g} = -\frac{M^2 N}{(2\beta + \gamma N - \gamma)(M+1)}(\alpha - \overline{c_o} - c_g - c_a) < 0 ,$$

$$\frac{\partial p_a}{\partial c_g} = -\frac{1}{M+1} < 0 ,$$

$$\frac{\partial q_a}{\partial c_g} = -\frac{N}{2(M+1)(2\beta + \gamma N - \gamma)} < 0 ,$$

$$\frac{\partial \pi_a}{\partial c_g} = -\frac{N(\alpha - \overline{c_o} - c_g - c_a)}{(M+1)^2(2\beta + \gamma N - \gamma)} < 0 ,$$

$$\frac{\partial \pi_o^j}{\partial c_g} = \frac{\partial\left(\beta q_o^{j2}\right)}{\partial c_g} < 0,$$

$$\frac{\partial \pi_g}{\partial c_g} = -\frac{M^2 N}{\left(2\beta + \gamma N - \gamma\right)\left(M+1\right)}\left(\alpha - \overline{c_o} - c_g - c_a\right) < 0.$$

The results for the NTO case can be proved in a similar fashion, and therefore we do not give the proof here.

Proof of Proposition 2.

Proof. We assume that *M* and *N* are continuous. Thus, for the WTO case, we have

$$\frac{\partial p_o^j}{\partial N} = \frac{-M\gamma\beta\alpha + \gamma\overline{c_o}(2\beta M - \gamma M - \beta - \gamma)}{2(M+1)(2\beta + \gamma N - \gamma)^2} < 0,$$

$$\frac{\partial q_o^j}{\partial N} = -\frac{M\gamma(\alpha - \overline{c_o} - c_g - c_a)}{2(M+1)(2\beta + \gamma N - \gamma)} < 0,$$

$$\begin{aligned}\frac{\partial \pi_o^j}{\partial N} = &-2\beta\Big(\frac{M(2\beta-\gamma)\alpha - (2\beta-\gamma)M(c_g + c_a) - 2(M+1)(2\beta+\gamma N-\gamma)c_o^j}{2(2\beta-\gamma)[2\beta+\gamma(N-1)](M+1)} + \\ &+ \frac{[(M+2)(2\beta-\gamma) + 2\gamma N(M+1)]\overline{c_o}}{2(2\beta-\gamma)[2\beta+\gamma(N-1)](M+1)}\Big)\frac{M\gamma(\alpha - \overline{c_o} - c_g - c_a)}{2(M+1)(2\beta+\gamma N-\gamma)^2} < 0\end{aligned},$$

$$\frac{\partial p_g}{\partial N} = 0,$$

$$\frac{\partial Q}{\partial N} = \frac{M(\alpha - \overline{c_o} - c_g - c_a)(2\beta - \gamma)}{2(M+1)(2\beta + \gamma N - \gamma)^2} > 0,$$

$$\frac{\partial \pi_g}{\partial N} = \frac{M^2(\alpha - \overline{c_o} - c_g - c_a)^2(2\beta - \gamma)}{2(M+1)(2\beta + \gamma N - \gamma)^2} > 0,$$

$$\frac{\partial p_a}{\partial N} = 0 \ ,$$

$$\frac{\partial q_a}{\partial N} = \frac{(\alpha - \overline{c_o} - c_g - c_a)(2\beta - \gamma)}{2(M+1)(2\beta + \gamma N - \gamma)^2} > 0 \, ,$$

$$\frac{\partial \pi_a}{\partial N} = \frac{(\alpha - \overline{c_o} - c_g - c_a)^2 (2\beta - \gamma)}{2(M+1)^2 (2\beta + \gamma N - \gamma)^2} > 0 \, .$$

For parameter *M*:

$$\frac{\partial p_o^j}{\partial M} = \frac{-\alpha(2\beta + \gamma N - \gamma) + \overline{c_o}(-\beta + \gamma N + \gamma) + (c_g + c_a)(\beta + \gamma N - \gamma)}{2(2\beta + \gamma N - \gamma)(M+1)^2} < 0 \, ,$$

$$\frac{\partial q_o^j}{\partial M} = \frac{\alpha - \overline{c_o} - c_g - c_a}{2(2\beta + \gamma N - \gamma)(M+1)^2} > 0 \, ,$$

$$\frac{\partial \pi_o^j}{\partial M} = \beta\Big(\frac{M(2\beta - \gamma)\alpha - (2\beta - \gamma)M(c_g + c_a) - 2(M+1)(2\beta + \gamma N - \gamma)c_o^j}{2(2\beta - \gamma)[2\beta + \gamma(N-1)](M+1)} + \\ + \frac{[(M+2)(2\beta - \gamma) + 2\gamma N(M+1)]\overline{c_o}}{2(2\beta - \gamma)[2\beta + \gamma(N-1)](M+1)}\Big)\frac{\alpha - \overline{c_o} - c_g - c_a}{(2\beta + \gamma N - \gamma)(M+1)^2} > 0 \, ,$$

$$\frac{\partial p_g}{\partial M} = -\frac{\alpha - \overline{c_o} - c_g - c_a}{2(M+1)^2} < 0 \, ,$$

$$\frac{\partial Q}{\partial M} = \frac{N(\alpha - \overline{c_o} - c_g - c_a)}{2(2\beta + \gamma N - \gamma)(M+1)^2} > 0 \, ,$$

$$\frac{\partial \pi_g}{\partial M} = \frac{N(\alpha - \overline{c_o} - c_g - c_a)^2 (M^2 + 2M)}{2(2\beta + \gamma N - \gamma)(M+1)^2} > 0 \, ,$$

$$\frac{\partial p_a}{\partial M} = -\frac{\alpha - \overline{c_o} - c_g - c_a}{(M+1)^2} < 0,$$

$$\frac{\partial q_a}{\partial M} = -\frac{N(\alpha - \overline{c_o} - c_g - c_a)}{2(\beta + \gamma N - \gamma)(M+1)^2} < 0,$$

$$\frac{\partial \pi_a}{\partial M} = -\frac{N(\alpha - \overline{c_o} - c_g - c_a)^2}{(2\beta + \gamma N - \gamma)(M+1)^3} < 0.$$

The proof of the results of the NTO case is similar, and therefore we do not give it here. This completes the proof.

Proof of Proposition 3.

Proof. For convenience, we assume that $\Delta c_o = \Delta c_o^j$; that is, when the TSC includes a TO, the cost reduction for all TAs is as follows:

$$\pi_g = \frac{M^2 N\left(\alpha - \overline{c_o} - c_g - c_a\right)^2}{2\left(2\beta + \gamma N - \gamma\right)\left(M+1\right)} > 0$$

$$\frac{Q}{Q'} - 1 = \frac{\Delta_1}{2\left(\alpha - \overline{c_o}' - c_a'\right)}$$

$$\frac{q_o^j}{q_o^{j\prime}} - 1 = \frac{\Delta_1}{2M\left(2\beta - \gamma\right)\left(\alpha - c_a'\right) + 2\left(\gamma NM + \gamma N + 2\beta - \gamma\right)\overline{c_o}' - 2\left(M+1\right)\left(2\beta + \gamma N - \gamma\right)c_o^{j\prime}}$$

$$\frac{\pi_o^j}{\pi_o^{j\prime}} - 1 = \frac{\left(q_o^j + q_o^{j\prime}\right)}{q_o^{j\prime}}\left(\frac{q_o^j}{q_o^{j\prime}} - 1\right)$$

$$\frac{\pi_a}{\pi_a'} - 1 = \frac{\left(\alpha - \overline{c_o} - c_g - c_a + \sqrt{2}\left(\alpha - \overline{c_o}' - c_a'\right)\right)\Delta_2}{2\left(\alpha - \overline{c_o}' - c_a'\right)^2} \quad .$$

It can be easily seen that $\Delta_2 > \Delta_1$. This completes the proof.

Proof of Proposition 4.

Proof. We first compare the effects of the number of TAs on both cases.

For the total quantity (demand), we have $\left|\frac{\partial Q}{\partial N}\right| / \left|\frac{\partial Q'}{\partial N}\right| - 1 = \frac{\Delta_1}{2\left(\alpha - \overline{c}_o' - c_a'\right)}$.

For the profit of a TA, $\frac{\partial \pi_o^j}{\partial N} = 2\beta q_o^j \frac{\partial q_o^j}{\partial N}$, $\frac{\partial \pi_o^{j'}}{\partial N} = 2\beta q_o^{j'} \frac{\partial q_o^{j'}}{\partial N}$.

We can prove that

$$\frac{q_o^j}{q_o^{j'}} - 1 = \frac{\Delta_1}{2M\left(2\beta - \gamma\right)\left(\alpha - c_a'\right) + 2\left(\gamma NM + \gamma N + 2\beta - \gamma\right)\overline{c}_o' - 2\left(M+1\right)\left(2\beta + \gamma N - \gamma\right)c_o^{j'}} ,$$

$$\left|\frac{\partial q_o^j}{\partial N}\right| / \left|\frac{\partial q_o^{j'}}{\partial N}\right| - 1 = \frac{\Delta_1}{2\left(\alpha - c_a' - \overline{c}_o'\right)} .$$

Hence, $\left|\frac{\partial \pi_o^j}{\partial N}\right| / \left|\frac{\partial \pi_o^{j'}}{\partial N}\right| - 1 = q_o^j \left|\frac{\partial q_o^{j'}}{\partial N}\right| \left(\left|\frac{\partial q_o^j}{\partial N}\right| / \left|\frac{\partial q_o^{j'}}{\partial N}\right| - 1 \right) + q_o^{j'} \left|\frac{\partial q_o^{j'}}{\partial N}\right| \left(\frac{q_o^j}{q_o^{j'}} - 1 \right)$.

For the profit of an HO, $\left|\frac{\partial \pi_a}{\partial N}\right| / \left|\frac{\partial \pi_a'}{\partial N}\right| - 1 = \frac{\left(\alpha - \overline{c}_o - c_g - c_a + \sqrt{2}\left(\alpha - \overline{c}_o' - c_a'\right)\right)\Delta_2}{2\left(\alpha - \overline{c}_o' - c_a'\right)^2}$.

We then prove the effects of *M*.

For the total quantity, we have $\left|\frac{\partial Q}{\partial M}\right| / \left|\frac{\partial Q'}{\partial M}\right| - 1 = \frac{\Delta_1}{2\left(\alpha - \overline{c}_o' - c_a'\right)}$.

For the profit of the TO, $\left|\frac{\partial \pi_o^j}{\partial M}\right| = 2\beta q_o^j \left|\frac{\partial q_o^j}{\partial M}\right|$, $\left|\frac{\partial \pi_o^{j'}}{\partial M}\right| = 2\beta q_o^{j'} \left|\frac{\partial q_o^{j'}}{\partial M}\right|$.

We can prove that $\left|\frac{\partial q_o^j}{\partial M}\right| / \left|\frac{\partial q_o^{j'}}{\partial M}\right| - 1 = \frac{\Delta_1}{2\left(\alpha - c_a' - \overline{c_o}'\right)}$.

Hence, $\left|\frac{\partial \pi_o^j}{\partial M}\right| / \left|\frac{\partial \pi_o^{j'}}{\partial M}\right| - 1 = q_o^j \left|\frac{\partial q_o^{j'}}{\partial M}\right| \left(\left|\frac{\partial q_o^j}{\partial M}\right| / \left|\frac{\partial q_o^{j'}}{\partial M}\right| - 1 \right) + q_o^{j'} \left|\frac{\partial q_o^{j'}}{\partial M}\right| \left(\frac{q_o^j}{q_o^{j'}} - 1 \right)$.

For the profit of the HOs, $\left|\frac{\partial \pi_a}{\partial M}\right| / \left|\frac{\partial \pi_a'}{\partial M}\right| - 1 = \frac{\left(\alpha - \overline{c_o} - c_g - c_a + \sqrt{2}\left(\alpha - \overline{c_o}' - c_a'\right)\right)\Delta_2}{2\left(\alpha - \overline{c_o}' - c_a'\right)^2}$.

This completes the proof.

References

Aguiló, E., J. Alegre, and M. Sard (2002). "Analysis of package holiday prices in the Balearic Islands. " Working Paper, University of the Balearic Islands, Palma de Mallorca.

Başar, T. (1986). *Dynamic Games and Applications in Economics*. Berlin, Heidelberg: Springer-Verlag.

Budeanu, A. (2005). "Impacts and Responsibilities for Sustainable Tourism: A Tour Operator's Perspective." *Journal of Cleaner Production*, 13(2): 89-97.

Buhalis, D. (2000). "Relationships in the Distribution Channel of Tourism: Conflicts between Hoteliers and Tour Operators in the Mediterranean Region." *International Journal of Hospitality and Tourism Administration*, 1(1): 113-139.

Buhalis, D. and E. Laws (2001). *Tourism Distribution Channels: Practices, Issues and Transformations*. London: Continuum International Publishing Group.

Cachon, G. P. and S. Netessine (2004). "Game Theoretic Application in Supply Chain Analysis." In *Handbook of Quantitative Supply Chain Analysis: Modeling in the E-Business Era*, Vol. 2., edited by David Simchi-Levi, S. David Wu, and Zuo-Jun (Max) Shen. Norwell, MA: Kluwer Academic Publishers.

Candela, G. and R. Cellini (2006). "Investment in Tourism Market: A Dynamic Model of Differentiated Oligopoly." *Environmental and Resource Economics*, 35(1): 41-58.

Carr, S.M. and U.S. Karmarkar (2005). "Competition in Multi-echelon Assembly Supply Chains." *Management Science*, 51(1): 45-59.

Choi, S.C. (1991). "Price Competition in a Channel Structure with a Common Retailer." *Marketing Science*, 10(4): 271-296.

Choi, S.C. (1996). "Price Competition in a Duopoly Common Retailer Channel." *Journal of Retailing*, 72(2): 117-134.

Dixit, A. (1979). "Quality and Quantity Competition." *Review of Economic Studies*, 46(4): 587-599.

García, D. and M. Tugores (2006). "Optimal Choice of Quality in Hotel Services." *Annals of Tourism Research*, 33(2): 456-469.

Huang, G.Q., W.L. Chen, H.Y. Song, and X.Y. Zhang (2010). "Game-theoretic Study of the Dynamics of Tourism Supply Chains for Package Holidays under Quantity Competition." *Tourism Economics*, 16(1): 197-216.

Huang, Y., G.Q. Huang, and S.T. Newman (2011). "Coordinating Pricing and Inventory Decisions in a Multi-level Supply Chain: A Game-theoretic Approach." *Transportation Research Part E: Logistics and Transportation Review*, 47(2): 115-129.

Medina-Muñoz, R.D., D.R. Medina-Muñoz, and J.M. García-Falcón (2003). "Understanding European Tour Operators' Control on Accommadation Companies: An Empirical Evidence." *Tourism Management*, 24(2): 135-147.

Minakshi, T. (1998). "Distribution Channels: An Extension of Exclusive Relationship." *Management Science*, 44(7): 896-909.

Netessine, S., and R. A. Shumsky (2005). "Revenue Management Games: Horizontal and Vertical Competition." *Management Science*, 51: 813-31.

Sheshinski, E. (1976). “Price, Quality and Quantity Regulation in Monopoly Situations.” *Economica*, 43(2): 127-137.

Tapper, R. and X. Font (2008). “Tourism Supply Chains.” http://www.leedsmet.ac.uk/lsif/the/Tourism_Supply_Chains.pdf (accessed January 3, 2008).

Theuvsen, L. (2004). “Vertical Integration in the European Package Tour Business.” *Annals of Tourism Research*, 31(2): 475-478.

Wie, B.W. (2005). “A Dynamic Game Model of Strategic Capacity Investment in the Cruise Line Industry.” *Tourism Management*, 26(2): 203-217.

Yang, S., G.Q. Huang, H.Y. Song, and L. Liang (2009). “Game-theoretic Approach to Competition Dynamics in Tourism Supply Chains.” *Journal of Travel Research*, 47(4): 425-439.

Zhang, X.Y., H.Y. Song, and G.Q. Huang (2009). “Tourism Supply Chain Management: A New Research Agenda.” *Tourism Management*, 30: 345-358.

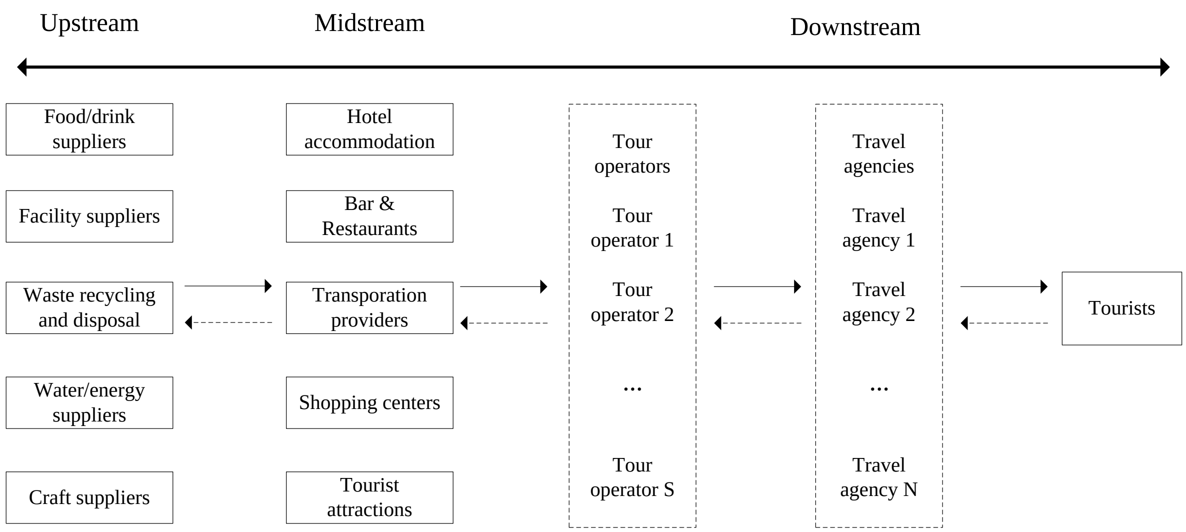
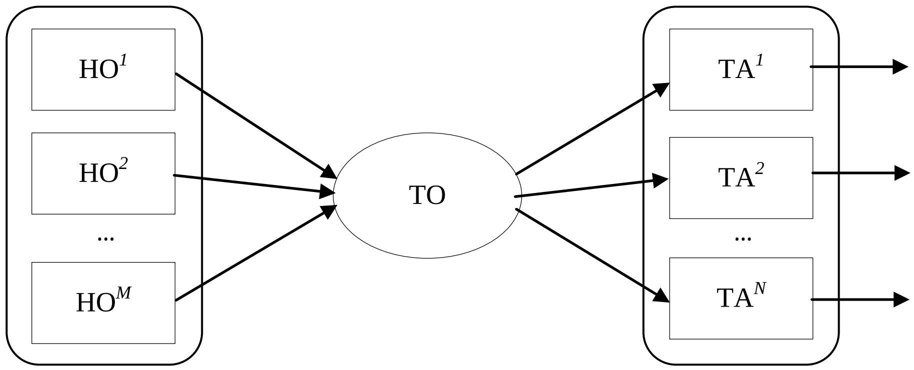
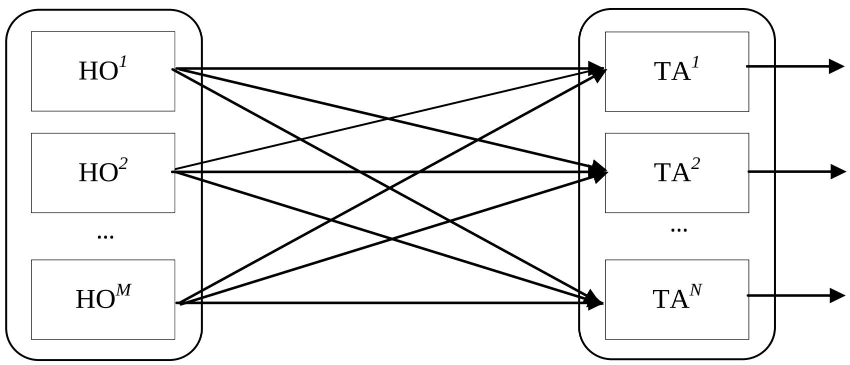


Fig. 1 A typical tourism supply chain

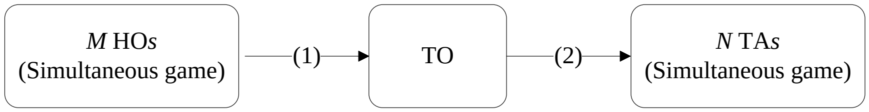


(a) TSC with a tour operator

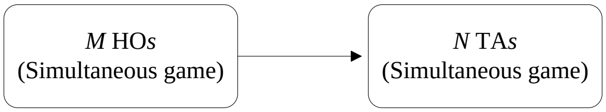


(b) TSC without a tour operator

Fig. 2 TSCs with and without a tour operator



(a) Game rule for WTO case



(b) Game rule for NTO case

Fig. 3 Game rules

Table 1. Notation for the WTO and NTO cases

	Room Rate /Service Charge	*Operating Cost*	*Room Quantity*	*Profit*
TA[j] ($j=1,\ldots,N$)	$p_o^{j(\grave{})}$	$c_o^{j(\grave{})}$	$q_o^{j(\grave{})}$	$\pi_o^{j(\grave{})}$
TO	p_g	c_g	q_g	π_g
HO[i] ($i=1,\ldots,M$)	$p_a^{i(\grave{})}$	$c_a^{i(\grave{})}$	$q_a^{i(\grave{})}$	$\pi_a^{i(\grave{})}$
Total quantity			$Q^{(\grave{})}$	

(*Note: Back quote* (`) *denotes the parameters and variables of the NTO case*)

Table 2. Results for the WTO and NTO cases

(a) Results of the WTO case

TA^j	p_o^j	$\frac{\left(\left(2\beta+\gamma(N-1)\right)(M+2)+M\beta\right)\alpha+M\left(\beta-\gamma+\gamma N\right)\left(c_a+c_g\right)}{2\left(2\beta+\gamma(N-1)\right)(M+1)}$ $+\frac{\left((\beta-\gamma)(M+2)+\gamma NM\right)\overline{c_o}}{2\left(2\beta+\gamma(N-1)\right)(M+1)}+\frac{\left(\gamma N(\beta-\gamma)\right)\overline{c_o}}{2(2\beta-\gamma)\left(2\beta+\gamma(N-1)\right)}+\frac{\beta-\gamma}{2\beta-\gamma}c_o^j$
	q_o^j	$\frac{M(2\beta-\gamma)\alpha-(2\beta-\gamma)M\left(c_g+c_a\right)-2(M+1)\left(2\beta+\gamma(N-1)\right)c_o^j}{2(2\beta-\gamma)\left(2\beta+\gamma(N-1)\right)(M+1)}+$ $+\frac{\left((M+2)(2\beta-\gamma)+2\gamma N(M+1)\right)\overline{c_o}}{2(2\beta-\gamma)\left(2\beta+\gamma(N-1)\right)(M+1)}$
	π_o^j	$\beta\left(q_o^j\right)^2$
TO	p_g	$\frac{(M+2)\left(\alpha-\overline{c_o}\right)+M\left(c_g+c_a\right)}{2(M+1)}$
	Q	$\frac{NM\left(\alpha-\overline{c_o}-c_g-c_a\right)}{2\left(2\beta+\gamma(N-1)\right)(M+1)}$
	π_g	$\frac{M^2N\left(\alpha-\overline{c_o}-c_g-c_a\right)^2}{2\left(2\beta+\gamma(N-1)\right)(M+1)}$
HA^i	p_a	$\frac{\alpha-\overline{c_o}-c_g+Mc_a}{M+1}$
	q_a	$\frac{N\left(\alpha-\overline{c_o}-c_g-c_a\right)}{2(M+1)\left(2\beta+\gamma(N-1)\right)}$
	π_a	$\frac{N\left(\alpha-\overline{c_o}-c_g-c_a\right)^2}{2(M+1)^2\left(2\beta+\gamma(N-1)\right)}$

(b) Results of the NTO case

TA^{j}	$q_o^{j`}$	$\dfrac{M(2\beta-\gamma)(\alpha-c_a^{`})+(\gamma NM+\gamma N+2\beta-\gamma)\overline{c_o^{`}}-(M+1)(2\beta+\gamma N-\gamma)c_o^{j`}}{(2\beta-\gamma)(2\beta+\gamma N-\gamma)(M+1)}$
	$p_o^{j`}$	$\dfrac{\beta M+2\beta+\gamma N-\gamma}{(M+1)(2\beta+\gamma(N-1))}\alpha+\dfrac{M(\beta+\gamma N-\gamma)}{(M+1)(2\beta+\gamma(N-1))}c_a^{`}+\dfrac{\beta-\gamma}{2\beta-\gamma}c_o^{j`}$ $+\dfrac{\beta\gamma MN-(\beta-\gamma)(2\beta+\gamma(N-1))}{(2\beta-\gamma)(M+1)(2\beta+\gamma(N-1))}\overline{c_o}^{`}$
	$\pi_o^{j`}$	$\beta\left(q_o^{j`}\right)^2$
HA^{i}	$p_a^{`}$	$\dfrac{\alpha-\overline{c_o}^{`}+Mc_a^{`}}{M+1}$
	$q_a^{`}$	$\dfrac{N\left(\alpha-\overline{c_o}^{`}-c_a^{`}\right)}{(M+1)(2\beta+\gamma(N-1))}$
	$\pi_a^{`}$	$\dfrac{N\left(\alpha-\overline{c_o}^{`}-c_a^{`}\right)^2}{(M+1)^2(2\beta+\gamma(N-1))}$

Table 3. Impacts of operating cost

		TA				TO		HO		$\Delta Q^{(')}$
		$\Delta p_o^{j(')}$	$\Delta \pi_o^{j(')}$	$\Delta p_o^{k(')}$	$\Delta \pi_o^{k(')}$	Δp_g	$\Delta \pi_g$	$\Delta p_a^{(')}$	$\Delta \pi_a^{(')}$	
$\alpha = 500$	$\Delta c_a = -15$	-5.21	6.51			-6.25	281.25	-12.50	28.13	1.56
	$\Delta c_a' = -15$	-10.41	31.83					-12.50	68.75	3.12
$\alpha = 600$	$\Delta c_a = -15$	-5.21	8.43			-6.25	385.42	-12.50	38.54	1.56
	$\Delta c_a' = -15$	-10.41	41.47					-12.50	89.58	3.12
$\alpha = 500$	$\Delta c_o^j = -15$	-5.81	469.80	-12.19	-6.24	0.97	4228.20	0.27	1.87	0.17
	$\Delta c_o^{j}{}' = -15$	-5.60	513.30	-5.41	-13.44			2.49	4.58	3.12
$\alpha = 600$	$\Delta c_o^j = -15$	-5.81	643.80	-12.19	-8.55	0.97	5794.20	0.27	2.56	0.17
	$\Delta c_o^{j}{}' = -15$	-5.60	688.90	-5.41	-17.51			2.49	5.96	3.12
$\alpha = 500$	$\Delta c_g = -15$	-1.04	6.53			-6.24	4218.70	2.50	1.87	1.56
$\alpha = 600$	$\Delta c_g = -15$	-1.04	8.95			-6.24	5781.20	2.50	2.56	1.56

(Benchmark data: N=9, M=5, $\alpha = 500$, $c_a = 50$, $c_g = 80$, $c_o^j = \overline{c_o} = 100$, $\beta = 6$, $\gamma = 3$, $c_a' = 60$, $c_o^{j}{}' = \overline{c_o}' = 110$)

Table 4. Impacts of TSC membership

			TA		TO		HO		$\Delta Q^{(`)}$
			$\Delta p_o^{j(`)}$	$\Delta \pi_o^{j(`)}$	Δp_g	$\Delta \pi_g$	$\Delta p_a^{(`)}$	$\Delta \pi_a^{(`)}$	
WTO	$\alpha = 500$	$N+1$	-2.20	-9.77	0	1054.69	0	7.03	0.78
		$M+1$	-4.51	3.93	-3.75	8859.38	-7.50	-84.38	0.94
	$\alpha = 600$	$N+1$	-2.78	-13.39	0	1980.60	0	13.20	1.07
		$M+1$	-5.90	5.38	-5.13	16637.15	-10.28	-158.45	1.28
NTO	$\alpha = 500$	$N+1$	-3.82	-45.09			0	21.01	1.91
		$M+1$	-7.64	17.48			-9.17	-252.08	2.29
	$\alpha = 600$	$N+1$	-4.98	-69.17			0	35.67	2.49
		$M+1$	-9.95	29.74			-11.94	-428.01	2.97

(Benchmark data: N=9, M=5, $\alpha = 500$, $c_a = 50$, $c_g = 80$, $c_o^j = \overline{c_o} = 100$, $\beta = 6$, $\gamma = 3$, $c_a` = 60$, $c_o^j` = \overline{c_o}` = 110$)

Table 5. Impacts of different TSCs

	$\pi_o^{j(')}$	$\pi_a^{(')}$	$Q^{(')}$
WTO	58.88	253.13	28.13
NTO	196.31	756.25	68.75

(Benchmark data: N=9, M=5, $\alpha = 500$, $c_a = 50$, $c_g = 80$, $c_o^j = \overline{c_o} = 100$, $\beta = 6$, $\gamma = 3$, $c_a' = 60$, $c_o^{j\prime} = \overline{c_o}' = 110$)