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Competing tourism service provider introduction strategy for an online travel platform with demand information sharing

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ABSTRACT

This paper considers a tourism supply chain (TSC) where an online travel platform (OTP) that holds private demand information cooperates with an incumbent tourism service provider (TSP) through the agency model. To expand the online travel markets and improve profitability, the OTP can further introduce the competing TSP using the agency model or the wholesale model. Based on a game model, we explore the OTP's introduction and demand information sharing strategies, and then study the Pareto improvement of the OTP's strategy choices. We find that both the price competition intensity and the commission rate influence the OTP's introduction choice, while the demand fluctuation and demand forecast accuracy also critically affect selection under certain conditions. In particular, the OTP may introduce the competing TSP even if the price competition is fierce. Moreover, the agency introduction strategy may hurt the OTP even though the commission rate is high under the agency model. The results also show that regardless of the chosen introduction strategy, the OTP always shares demand information with the agency cooperating TSP, and also may share it with the wholesale cooperating TSP. In addition, the OTP's strategy choices may lend to the inefficiency of the TSC, and the Pareto improvement in introduction strategy or (and) demand information sharing strategy can be realized by implementing three types of transfer payment contracts.

1. Introduction

With the rise of e-commerce, the online travel market is booming in recent years (He et al., 2019; Teubner and Graul, 2020). As one of the most active online travel markets worldwide, the Chinese online travel market was reported to reach nearly \$260 billion (1.8 trillion yuan) transaction volume in 2019 and keep an annual growth rate of 18.8% (Statista, 2020). Moreover, Allied Market Research (2017) reported that the online travel sales worldwide is expected to reach \$1.091 trillion in 2022. As an important transaction intermediary in the online travel market, online travel platforms (OTPs) offer consumers the convenient channels to directly purchase various tourism services by cooperating with lots of agency selling tourism service providers (TSPs) (Rianthong et al., 2016; Ye et al., 2018). Taking Chinese OTPs as an example, the number of consumers who directly purchased from the Chinese OTPs reached nearly 150 million until June 2019, and the transaction volume of the Chinese OTPs accounted for approximately 70% of Chinese online travel sales in the first quarter of 2019 (ChinaTravelNews, 2019a).

In addition to cooperating with the incumbent agency selling TSP, some OTPs also introduce the competing TSPs using the agency model or the wholesale model to satisfy consumers' diversified needs and improve profitability. For example, Fliggy.com first cooperated with the agency selling Hilton Hotel and then introduced Accor Hotel Group using the agency model to sell the substituted hotel rooms (ChinaTravelNews, 2019b). Conversely, tuniu.com, a leading online leisure travel platform in China, not only acted as an agent for the sale of the destination tourism services in overseas such as Japan and Thailand, but also adopted the wholesale model to introduce the competing TSP to resell the substituted tourism services (PR Newswire, 2018). Although the introduction of competing TSP can improve consumer satisfaction and expand the online travel markets (Zhang et al., 2021), it also causes tourism services competition, which may lead to channel conflict. Hence, OTPs need to weigh the pros and cons to decide whether to introduce a competing TSP. Moreover, there are differences in pricing right and profits acquisition between the agency introduction strategy and the wholesale introduction strategy (Abhishek et al., 2016). To be specific, under the agency introduction strategy, the OTP does not gain the pricing right of the introduction tourism service and charges the

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competing TSP a commission fee for profits. In comparison, under the wholesale introduction strategy, the OTP gets the pricing right of the introduction tourism service, and profits by earning the spread. As a result, the cooperation model choice, the agency model or the wholesale model, is a critical issue for an OTP when introducing the competing TSP.

Besides, due to the influence of the tourism seasonality and other random factors of the online travel market (Zhang et al., 2009), OTPs' potential market demand is uncertain, which creates a great challenge for their introduction strategy choice. However, compared with TSPs, OTPs can better capture the market conditions and often possess stronger demand forecasting capabilities because of the closer position to the end market (Li et al., 2018; Zhu et al., 2019). Therefore, OTPs have information advantages in coping with the demand fluctuations risk. OTPs can share with TSPs, which helps TSPs make pricing decisions in response to the potential market demand. Nevertheless, demand information sharing induces OTPs to lose its information advantages and enables informed TSPs to strategically adjust pricing decisions, which may be harmful to OTPs. Accordingly, when choosing the introduction strategy, an OTP is also confronted with a decision on whether to share information with TSPs or not.

Based on the above discussions, we will address the following questions.

(1) Whether an OTP should introduce the competing TSP, and if so, should the agency introduction strategy or the wholesale introduction strategy be adopted?
(2) Under different introduction strategies, what is the OTP's optimal demand information sharing strategy?
(3) Is there possible for the Pareto improvement of the OTP's strategy choices, and if yes, how to realize a Pareto improvement?

To address the problems mentioned above, we focus on a tourism supply chain (TSC) in which an OTP partners with an incumbent agency selling TSP. The OTP possessing private demand information can further introduce the competing TSP via the agency or wholesale model to satisfy consumers' diversified needs. By modelling a multistage game, we first investigate the OTP's optimal demand information sharing strategy under different introduction strategies, then examine the OTP's optimal introduction strategy and finally explore the Pareto improvement of the OTP's strategy choices. The results show that the OTP always shares demand information under the no introduction and the agency introduction strategies. However, under the wholesale introduction strategy, the OTP shares with both competing TSPs under certain conditions. Besides, the competition intensity and the commission rate always affect the introduction choice of the OTP, and the demand fluctuation and demand forecast accuracy also have an impact under certain conditions. Interestingly, the OTP may introduce the competing TSP even if the price competition is fierce. Moreover, the agency introduction strategy may hurt the OTP even though the agency model's commission rate is high. Additionally, the OTP's strategy choices may lend to the TSC's inefficiency. By analyzing the regions where the OTP's and the TSC's optimal strategies are inconsistent, we derive that there is possible for the Pareto improvement in OTP's introduction selection or (and) information sharing decision, and the OTP can design contract to achieve Pareto improvement.

The rest of this paper is organized as follows. In Section 2, the related literature is reviewed. Section 3 characterizes the model. Section 4 derives the OTP's and the TSPs' optimal decisions and expected profits under different strategies. Section 5 first explores the OTP's optimal demand information sharing strategy under different introduction strategies, then investigates the OTP's optimal introduction strategy and finally examines the Pareto improvement of the OTP's strategy choices. The extension that the wholesale model is applied with the TSP1 is explored in Section 6. In Section 7, we conclude this paper.

2. Literature review

Our work is related to two literature streams: (1) the OTP's channel cooperation, and (2) demand information sharing in supply chain.

2.1. The OTP's channel cooperation

Due to the rise of OTPs, the OTP's channel cooperation has been well explored by scholars. In the early stage, OTPs mainly cooperates with offline TSPs via the agency model. Hence, a great deal of researchers have focused on the OTP's channel cooperation under the agency model. They have explored topics such as pricing (Guo et al., 2013), effort or service decision (Ling et al., 2014; Guo et al., 2014), O2O cooperation (Long and Shi, 2017) and opaque selling (Mao et al., 2019). To effectively stimulate tourism demand and improve profitability, some OTPs have gradually cooperated with offline TSPs using the wholesale model. Accordingly, several scholars considered channel cooperation under the wholesale model and investigated the issue of NYOP service (Huang et al., 2017a) and overbooking (Ye et al., 2019a). However, these studies primarily examined the OTP's or the TSPs' operational decisions under either the agency or wholesale model.

As competition intensifies, more and more OTPs have begun to adopt differentiated cooperation models (e.g. the agency or wholesale model) to partner with various TSPs to sell different tourism services. Therefore, some scholars have gradually begun to pay attention to the cooperation model selection between the OTP and the TSPs. For instance, Ye et al. (2018) discuss whether the hotel with a direct channel should sell on the OTP using the agency or wholesale model. They show that the hotel's choice is mainly driven by the OTP's consumer acceptance, the market size and the room capacity. Liao et al. (2019) explore the OTP's cooperation model selection and the hotel's channel choice through a two period model. Ye et al. (2019b) investigate a hotel's online selling choice between the direct selling and the OTP selling (e.g. either the agency or wholesale model). The results show that a hotel's strategy is affected by negotiation power, market size and selling cost. He et al. (2019) explore the influence of corporate social responsibility on the OTP's and the TSP's selection between the agency, wholesale or hybrid model. Ye et al. (2020) focus on a TSC including an OTP and two competing hotels, and they analyze how the market size, price completion and the commission rate impact the two competing hotels' cooperation model choices.

Among the above channel cooperation studies, the literature on cooperation model choice is most related to our work. However, these researches pay attention to the constant online travel demand and also do not explore the issue of competing TSP introduction. In contrast to this stream of literature, we examine the OTP's cooperation model selection when the competing TSP is introduced. Moreover, due to the demand fluctuations, the OTP's cooperation model choice becomes more complex. Hence, we also explore the influence of the market demand fluctuation and demand forecast accuracy on the OTP's cooperation model selection.

2.2. Demand information sharing in supply chain

A supply chain is often faced with uncertain market demand, and demand information sharing plays a vital role in coping with demand fluctuations and improving supply chain efficiency. Therefore, many scholars have investigated demand information sharing in supply chain. Due to the closer position to the consumers, the downstream member in supply chain usually possesses demand forecasting advantages (Li, 2002). Hence, a large number of literature investigates downstream demand information sharing in various channel structures such as "one-to-one" (Lee et al., 2000; Li and Zhang, 2015), downstream competition (Li, 2002; Jain et al., 2011; Zhou et al., 2017), upstream competition (Shang et al., 2016; Huang et al., 2017b; Lei et al., 2020) and competing supply chains (Ha and Tong, 2008; Ha et al., 2017; Guan et al., 2020). We discuss the downstream OTP's demand information sharing when

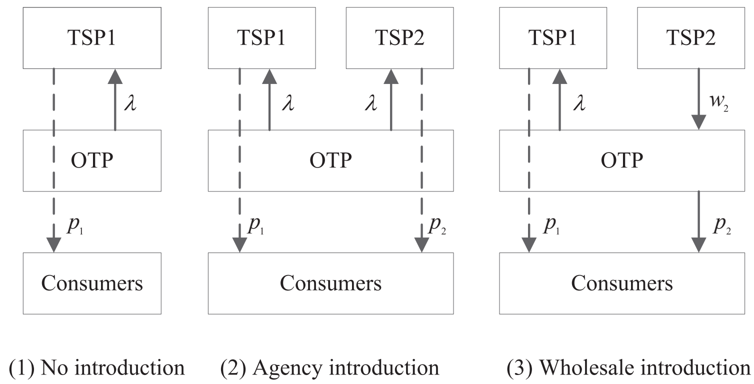

Fig. 1. Channel structures under different introduction strategies.

introducing competing upstream TSP. Thus, the above literature on upstream competition is more related to our paper, and we mainly review this stream of literature as follows.

In these studies, Shang et al. (2016) explore a retailer's demand information sharing with the two competing manufacturers considering the influence of production economy/diseconomy, competition intensity and incentive contract. The results show that with side payment, the retailer shares demand information if production economy/diseconomy is high or competition is fierce. Considering the same supply chain structure, Jiang and Hao (2016) study how the information sharing contract influences a retailer's demand information sharing choice. They point out that suppliers have no motivation to obtain the retailer's demand signal by designing the information sharing contract. Huang et al. (2017b) focus on a supply chain with multiple suppliers and one retailer and examine the role of demand information sharing in reducing inventory level and suppliers' total costs. Lei et al. (2020) consider a retailer's ex post demand information sharing with two suppliers, and they show that the retailer may share low state demand signal with two suppliers, but would withhold high state demand signal.

The above literature on demand information sharing considering upstream competition mainly focuses on downstream member's information sharing with the wholesale cooperating upstream member. Moreover, these studies do not consider the issue of competing upstream introduction. Different from these studies, we explore whether the downstream OTP should introduce the competing upstream TSP and examine the OTP's demand information sharing with the cooperating TSPs under either the agency or wholesale model.

3. The model

3.1. Channel structure and demand functions

Considering a tourism supply chain (TSC) in which an online travel platform (OTP) cooperates with an agency selling tourism service provider (TSP1) to sell tourism service 1 under demand uncertainty. The TSP1 sells directly to consumers at retail price p_1 and shares λ rate of its revenues with the OTP as the commission fee, as shown in Fig. 1(1). In addition, the OTP can introduce the competing tourism service provider (TSP2) using the agency or wholesale model to sell the substituted tourism service 2. If the OTP adopts the agency model to introduce the TSP2, similar to the TSP1, the TSP2 sells to consumers at retail price p_2 and pays a commission rate λ to the OTP, as presented in Fig. 1(2). If the OTP introduces the TSP2 via the wholesale model, then the TSP2 wholesales its service to the OTP at price w_2, who resells to consumers at retail price p_2 further, as illustrated in Fig. 1(3). Although the commission rate of different types of tourism services varies, the OTP usually sets the uniform commission rate for the same category of tourism services and does not determine a separate commission rate for every agency selling TSP. That is, the commission rate for the same category of tourism services is rarely changed. Therefore, we assume that $\lambda \in (0,1)$ is exogenous, which is also consistent with lots of previous papers, such as in the research on tourism management (e.g. Ye et al., 2018; He et al., 2019; Ye et al., 2020) and retail platforms (e.g. Geng et al., 2018; Song et al., 2020).

Consumers' purchase decisions are influenced by the tourism service price. When the OTP does not introduce the competing TSP2, we assume that the tourism service 1′s demand function D_1 is as follows:

$$D_1 = a - p_1 \tag{1}$$

where a denotes the potential market demand for tourism services, which is uncertain. Following Jiang et al. (2016) and Zhang et al. (2019), we assume that the potential market demand can be either a high state ($a = H$) or a low state ($a = L$), and the probability of occurrence is equal to 1/2 (i.e., $Pr(a = H) = Pr(a = L) = 1/2$). We further assume that $H = (1+\Delta)\overline{a}$ and $L = (1-\Delta)\overline{a}$, where $\overline{a}$ is the average of demand and $\Delta \in (0,1)$ refers to the demand uncertainty level.

When the OTP introduces the competing TSP2, referring to Huang et al. (2018), the tourism service $i's$ ($i \in \{1,2\}$) demand function is as follows:

$$D_i = \frac{1}{1+\gamma}\left(a - \frac{1}{1-\gamma}p_i + \frac{\gamma}{1-\gamma}p_{3-i}\right) \tag{2}$$

where $\gamma \in (0,1)$ represents the intensity of price competition.

3.2. Information structures

Since obtaining a huge amount of demand information, the OTP often holds demand information forecasting advantages in comparison with the TSPs. Therefore, we assume that the OTP can observe a private demand signal $Y \in \{h, l\}$ about the potential market demand a. The demand signal h and l denote the demand may be in a high state H and a low state L, respectively. The demand forecast is an unbiased estimation of the demand state, that is, $Pr(h) = Pr(H)$ and $Pr(l) = Pr(L)$. Moreover, following Jiang et al. (2016), we define $\rho = Pr(h|H) + Pr(l|L) - 1$ as the OTP's demand signal accuracy further. If the demand forecast is completely reliable (i.e., $Pr(h|H) = Pr(l|L) = 1$), $\rho = 1$ can be derived. If the demand forecast is completely unreliable (i.e., $Pr(h|H) = Pr(H)$ and $Pr(l|L) = Pr(L)$), $\rho = 0$ can be obtained. If demand forecast is not completely accurate (i.e., $Pr(h) < Pr(h|H) < 1$ and $Pr(l) < Pr(l|L) < 1$), we can show that $0 < \rho < 1$. Based on the assumptions above, we can derive that $Pr(H|h) = Pr(L|l) = (1+\rho)/2$ and $Pr(L|h) = Pr(H|l) = (1-\rho)/2$. Hence, it can be further obtained that:

$$E[a|h] = Pr(H|h)H + Pr(L|h)L = (1+\rho\Delta)\overline{a} \tag{3}$$

$$E[a|l] = Pr(L|l)L + Pr(H|l)H = (1-\rho\Delta)\overline{a} \tag{4}$$

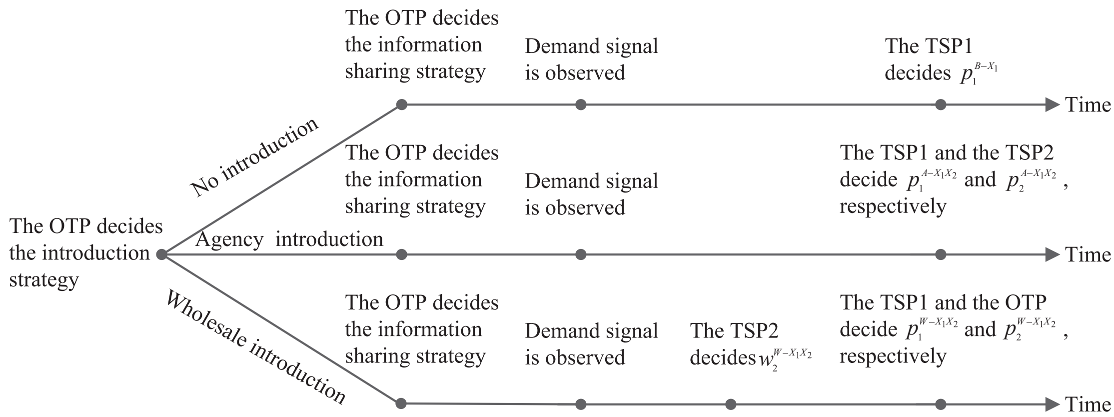

Fig. 2. The sequence of events.

Table 1
Summary of notations.

Notations	Definitions
Indexes	
$i \in \{1,2\}$	Subscript, index of the tourism service$i$
$j \in \{OTP, TSP1, TSP2, TSC\}$	Subscript, index of the online travel platform, the tourism service providers, the tourism supply chain, respectively
$M \in \{B,A,W\}$	Superscript, index of introduction strategy (no introduction, agency introduction, wholesale introduction)
$X_i \in \{I,N\}$;	Superscript, index of the OTP's information sharing strategy with the TSPi (information sharing, no information sharing)
Z	Superscript, index of strategy scenario,$Z \in \{B-X_1, A-X_1X_2, W-X_1X_2\}$
Parameters	
$a \in \{H,L\}$	The potential market demand (high state, low state)
$\bar{a}$, Δ	The average of potential market demand, demand uncertainty level
λ, γ	The commission rate, the price competition intensity
$Y \in \{h, l\}$	The demand signal (high demand signal, low demand signal)
ρ, $\rho\Delta$,τ	The demand signal accuracy, the forecast variability, the forecast variability's threshold value
π_j^Z	j'sexpected profits under Z strategy
$\bar{\pi}_j^M$	j'sdeterministic profits under M introduction strategy
V_j^Z	j'sinformation sharing profits under Z strategy
F_{OTP}^M, F_{TSC}^M	The OTP's and the TSC's forecast profits under M introduction strategy
ZB, ZA	The OTP's optimal strategy before and after the Pareto improvement
Λ_j	The expected profits difference of j after the Pareto improvement,$\Lambda_j = \pi_j^{ZA} - \pi_j^{ZB}$
T_{TSPi}, TP	The fixed fee charged or subsidized by the OTP to the TSPi, the transfer payment contract
Decision variables	
p_i^Z, w_i^Z	The retail price and wholesale price of tourism service i under Z strategy

3.3. Sequence of events

Considering that the competing TSP introduction and the demand information sharing strategy are long-term decisions, while the pricing decisions are easier to adjust in the short-term. Therefore, we assume that the OTP decides the introduction and demand information sharing strategies before pricing decisions. Besides, when choosing the introduction strategy, the OTP needs to conduct on-site investigations on the TSP, such as identifying tourism service categories, reviewing tourism service qualifications, and confirming tourism service procedures. Moreover, if the OTP introduces the competing TSP, then contract signing and the integration of online sales process with the TSP are also required. These activities tend to last a long time. However, for the demand information sharing decision, since the OTP often has a mature IT systems for information collection and sharing, the OTP only needs to carry out information exchange with the TSP when deciding to share demand information. This kind of pre-activity requires a relatively short time. Hence, we further assume that the OTP first decides the introduction strategy and then chooses to share information or not. Similar treatment is also common in studies (e.g. Zhang and Zhang, 2020). The sequence of events is given below.

(1) The OTP first decides the introduction strategy. Let $M \in \{B, A, W\}$ denotes the introduction strategy, where $M = B$ if the OTP does not introduce the competing TSP, and $M = A(M = W)$ if the OTP introduces the competing TSP using the agency model (the wholesale model). Then, the OTP chooses the demand information sharing strategy. Let $X_i \in \{I, N\}$ represents the demand information sharing strategy, where $X_i = I(X_i = N)$ if the TSPi is (is not) informed of the information. Hence, there are ten strategy scenarios, which are defined as $Z \in \{B-N, B-I, A-NN, A-IN, A-NI, A-II, W-NN, W-IN, W-NI, W-II\}$.
(2) The OTP obtains signal Y and shares it or not according to previous decision. Next, pricing decisions are made by the OTP and the TSPs. Particularly, under the no introduction strategy, the TSP1 sets the tourism service price $p_1^{B-X_1}$. Under the agency introduction strategy, the TSP1 and the TSP2 decide the tourism service price $p_1^{A-X_1X_2}$ and $p_2^{A-X_1X_2}$, respectively. Under the wholesale introduction strategy, the TSP2 sets the wholesale price $w_2^{W-X_1X_2}$ first, and then the OTP and the TSP1 choose the tourism service price $p_1^{W-X_1X_2}$ and $p_2^{W-X_1X_2}$, respectively.
(3) The demand and the TSC members' profits are realized. Fig. 2 shows the sequence of events.

All the notations are showed in Table 1.

4. Equilibrium analysis

In this section, the OTP's and the TSPs' optimal decisions and expected profits under different strategies are derived. To simplify the expressions, let π_j^Z denotes $j's$ expected profits under Z strategy. Let $\bar{\pi}_j^M$ be the deterministic profits of j under $M \in \{B, A, W\}$ introduction strategy. Besides, V_j^Z represents $j's$ information sharing profits under Z strategy. F_{OTP}^M (F_{TSC}^M) refers to the OTP's (the TSC's) forecast profits under M introduction strategy.

Table 2
The equilibrium results under the no introduction strategy.

	$B-N$	$B-I$
$p_1^{B-X_1}$	$\bar{a}/2$	$E[a\|Y]/2$
$E[\pi_{TSP1}^{B-X_1}]$	$\bar{\pi}_{TSP1}^{B}$	$\bar{\pi}_{TSP1}^{B} + V_{TSP1}^{B-I}$
$E[\pi_{OTP}^{B-X_1}]$	$\bar{\pi}_{OTP}^{B}$	$\bar{\pi}_{OTP}^{B} + V_{OTP}^{B-I}$

Table 3
The equilibrium results under the agency introduction strategy.

	$A-II$	$A-IN$	$A-NI$	$A-NN$
$p_1^{A-X_1X_2}$	$\frac{(1-\gamma)E[a\|Y]}{2-\gamma}$	$\frac{\gamma(1-\gamma)\bar{a}}{2(2-\gamma)} + \frac{(1-\gamma)E[a\|Y]}{2}$	$\frac{(1-\gamma)\bar{a}}{2-\gamma}$	$\frac{(1-\gamma)\bar{a}}{2-\gamma}$
$p_2^{A-X_1X_2}$	$\frac{(1-\gamma)E[a\|Y]}{2-\gamma}$	$\frac{(1-\gamma)\bar{a}}{2-\gamma}$	$\frac{\gamma(1-\gamma)\bar{a}}{2(2-\gamma)} + \frac{(1-\gamma)E[a\|Y]}{2}$	$\frac{(1-\gamma)\bar{a}}{2-\gamma}$
$E[\pi_{TSP1}^{A-X_1X_2}]$	$\bar{\pi}_{TSP1}^{A} + V_{TSP1}^{A-II}$	$\bar{\pi}_{TSP1}^{A} + V_{TSP1}^{A-IN}$	$\bar{\pi}_{TSP1}^{A}$	$\bar{\pi}_{TSP1}^{A}$
$E[\pi_{TSP2}^{A-X_1X_2}]$	$\bar{\pi}_{TSP2}^{A} + V_{TSP2}^{A-II}$	$\bar{\pi}_{TSP2}^{A}$	$\bar{\pi}_{TSP2}^{A} + V_{TSP2}^{A-NI}$	$\bar{\pi}_{TSP2}^{A}$
$E[\pi_{OTP}^{A-X_1X_2}]$	$\bar{\pi}_{OTP}^{A} + V_{OTP}^{A-II}$	$\bar{\pi}_{OTP}^{A} + V_{OTP}^{A-IN}$	$\bar{\pi}_{OTP}^{A} + V_{OTP}^{A-NI}$	$\bar{\pi}_{OTP}^{A}$

4.1. The equilibrium results under the no introduction strategy

Under $B-N$ strategy, the TSP1 determines the tourism service price p_1^{B-N} based on $E[a]$. Hence, the TSP1′s expected profits under $B-N$ strategy are as follows:

$$E[\pi_{TSP1}^{B-N}] = (1-\lambda)p_1^{B-N}(E[a] - p_1^{B-N}) \tag{5}$$

Under $B-I$ strategy, the informed TSP1 considers the expected market demand $E[a|Y]$ when deciding the tourism service price p_1^{B-I}. Therefore, the TSP1′s expected profits under $B-I$ strategy are given by:

$$E[\pi_{TSP1}^{B-I}|Y] = (1-\lambda)p_1^{B-I}(E[a|Y] - p_1^{B-I}) \tag{6}$$

The OTP holds private demand information, and its expected profits under the no introduction strategy are as follows:

$$E[\pi_{OTP}^{B-X_1}|Y] = \lambda p_1^{B-X_1}(E[a|Y] - p_1^{B-X_1}) \tag{7}$$

Theorem 1. *The equilibrium results under the no introduction strategy are shown in* Table 2.
where $\bar{\pi}_{TSP1}^{B} = (1-\lambda)\bar{a}^2/4$ and $\bar{\pi}_{OTP}^{B} = \lambda\bar{a}^2/4$. $V_{TSP1}^{B-I} = (1-\lambda)\rho^2\Delta^2\bar{a}^2/4$ and $V_{OTP}^{B-I} = \lambda\rho^2\Delta^2\bar{a}^2/4$.

Theorem 1 shows that the informed TSP1 adjusts p_1^{B-I} accordingly based on the demand signal under the no introduction strategy due to the more precise demand information (i.e., $\partial p_1^{B-I}/\partial E[a|Y] > 0$). Theorem 1 also demonstrates that the OTP and the TSP1 only gain the deterministic profits under $B-N$ strategy. However, under $B-I$ strategy, the OTP′s and the TSP1′s expected profits include the deterministic profits and information sharing profits.

4.2. The equilibrium results under the agency introduction strategy

Under $A-NX_2$ strategy, the TSP1 considers the expected market demand $E[a]$ and the price of tourism service 2 $E[p_2^{A-NX_2}]$ when determining the price of tourism service 1 $p_1^{A-NX_2}$. Thus, the TSP1′s expected profits under $A-NX_2$ strategy are given by:

$$E[\pi_{TSP1}^{A-NX_2}] = \frac{(1-\lambda)p_1^{A-NX_2}}{1+\gamma}\left(E[a] - \frac{1}{1-\gamma}p_1^{A-NX_2} + \frac{\gamma}{1-\gamma}E[p_2^{A-NX_2}]\right) \tag{8}$$

Under $A-IX_2$ strategy, the informed TSP1′s expected market demand and the price of tourism service 2 are $E[a|Y]$ and $E[p_2^{A-NX_2}|Y]$, respectively. At this moment, the TSP1′s expected profits under $A-IX_2$ strategy are shown as follows:

$$E[\pi_{TSP1}^{A-IX_2}|Y] = \frac{(1-\lambda)p_1^{A-IX_2}}{1+\gamma}\left(E[a|Y] - \frac{1}{1-\gamma}p_1^{A-IX_2} + \frac{\gamma}{1-\gamma}E[p_2^{A-IX_2}|Y]\right) \tag{9}$$

Due to the symmetry of the TSP1 and the TSP2, the TSP2′s expected profits are the same as the TSP1.

Moreover, the OTP′s expected profits under the agency introduction strategy are as follows:

$$E[\pi_{OTP}^{A-X_1X_2}|Y] = \frac{\lambda p_1^{A-X_1X_2}}{1+\gamma}\left(E[a|Y] - \frac{1}{1-\gamma}p_1^{A-X_1X_2} + \frac{\gamma}{1-\gamma}p_2^{A-X_1X_2}\right) + \frac{\lambda p_2^{A-X_1X_2}}{1+\gamma}\left(E[a|Y] - \frac{1}{1-\gamma}p_2^{A-X_1X_2} + \frac{\gamma}{1-\gamma}p_1^{A-X_1X_2}\right) \tag{10}$$

Theorem 2. *The equilibrium results under the agency introduction strategy are given in* Table 3.

where $\bar{\pi}_{TSP1}^{A} = \bar{\pi}_{TSP2}^{A} = \frac{(1-\gamma)(1-\lambda)\bar{a}^2}{(1+\gamma)(2-\gamma)^2}$ and $\bar{\pi}_{OTP}^{A} = \frac{2(1-\gamma)\lambda\bar{a}^2}{(1+\gamma)(2-\gamma)^2}$. $V_{TSP1}^{A-II} = V_{TSP2}^{A-II} = \frac{(1-\gamma)(1-\lambda)\rho^2\Delta^2\bar{a}^2}{(1+\gamma)(2-\gamma)^2}$, $V_{TSP1}^{A-IN} = V_{TSP2}^{A-NI} = \frac{(1-\gamma)(1-\lambda)\rho^2\Delta^2\bar{a}^2}{4(1+\gamma)}$, $V_{OTP}^{A-II} = \frac{2(1-\gamma)\lambda\rho^2\Delta^2\bar{a}^2}{(1+\gamma)(2-\gamma)^2}$ and $V_{OTP}^{A-IN} = V_{OTP}^{A-NI} = \frac{(1-\gamma)\lambda\rho^2\Delta^2\bar{a}^2}{4(1+\gamma)}$.

Theorem 2 indicates that under the agency introduction strategy, the informed TSP′s decision responds positively to signal Y because of the more accurate demand information (i.e., $\partial p_1^{A-IX_2}/\partial E[a|Y] > 0$ and $\partial p_2^{A-X_1I}/\partial E[a|Y] > 0$). Besides, the more TSPs obtain demand information, the stronger the positive impact of the demand information sharing on the informed TSPs' price decisions (i.e., $\partial p_i^{A-II}/\partial E[a|Y] > \partial p_1^{A-IN}/\partial E[a|Y] = \partial p_2^{A-NI}/\partial E[a|Y]$). Theorem 2 also states that under $A-NN$ strategy, the TSC members only gain the deterministic profits. Under the other three strategies, the OTP and the informed TSP also get the information sharing profits.

4.3. The equilibrium results under the wholesale introduction strategy

Since the TSP1 cannot observe the TSP2′s wholesale price, the TSP1 considers the expected demand and the OTP′s price in making decision. Under $W-NX_2$ strategy, the TSP1′s expected demand and the OTP′s price are $E[a]$ and $E[p_2^{W-NX_2}]$. Hence, the expected profits of the TSP1 under $W-NX_2$ strategy are as follows:

$$E[\pi_{TSP1}^{W-NX_2}] = \frac{(1-\lambda)p_1^{W-NX_2}}{1+\gamma}\left(E[a] - \frac{1}{1-\gamma}p_1^{W-NX_2} + \frac{\gamma}{1-\gamma}E[p_2^{W-NX_2}]\right) \tag{11}$$

Under $W-IX_2$ strategy, the informed TSP1 considers $E[a|Y]$ and $E[p_2^{W-NX_2}|Y]$ when determining $p_1^{W-IX_2}$. Hence, the TSP1′s expected profits under $W-IX_2$ strategy are given by:

$$E[\pi_{TSP1}^{W-IX_2}|Y] = \frac{(1-\lambda)p_1^{W-IX_2}}{1+\gamma}\left(E[a|Y] - \frac{1}{1-\gamma}p_1^{W-IX_2} + \frac{\gamma}{1-\gamma}E[p_2^{W-IX_2}|Y]\right) \tag{12}$$

For the OTP, its tourism service price decision is influenced by the TSP1′s and the TSP2′s decisions, and its expected profits under the wholesale introduction strategy are as follows:

$$E[\pi_{OTP}^{W-X_1X_2}|Y] = \frac{\lambda E[p_1^{W-X_1X_2}|Y]}{1+\gamma}\left(E[a|Y] - \frac{1}{1-\gamma}E\left[p_1^{W-X_1X_2}|Y\right] + \frac{\gamma}{1-\gamma}p_2^{W-X_1X_2}\right) + \frac{(p_2^{W-X_1X_2} - w_2^{W-X_1X_2})}{1+\gamma}\left(E[a|Y] - \frac{1}{1-\gamma}p_2^{W-X_1X_2} + \frac{\gamma}{1-\gamma}E[p_1^{W-X_1X_2}|Y]\right) \tag{13}$$

The TSP2′s wholesale price decision is influenced by the expected

Table 4
The equilibrium results under the wholesale introduction strategy.

	$W-II$	$W-IN$	$W-NI$	$W-NN$
$p_1^{W-X_1X_2}$	$(4+3\gamma)g_1E[a\|Y]$	$2(2+\gamma)g_1E[a\|Y]+\gamma g_1\overline{a}$	$(4+3\gamma)g_1\overline{a}$	$(4+3\gamma)g_1\overline{a}$
$p_2^{W-X_1X_2}$	$g_1(g_2+2)E[a\|Y]$	$g_1g_2E[a\|Y]+2g_1\overline{a}$	$3(1-\gamma)E[a\|Y]/4+(3+\lambda)g_1g_3\overline{a}/4$	$(1-\gamma)E[a\|Y]/2+g_1g_5\overline{a}/2$
$w_2^{W-X_1X_2}$	$2g_1g_4E[a\|Y]$	$2g_1g_4\overline{a}$	$(1-\gamma)E[a\|Y]/2+(1-\lambda)g_1g_3\overline{a}/2$	$2g_1g_4\overline{a}$
$E[\pi_{TSP1}^{W-X_1X_2}]$	$\overline{\pi}_{TSP1}^W+V_{TSP1}^{W-II}$	$\overline{\pi}_{TSP1}^W+V_{TSP1}^{W-IN}$	$\overline{\pi}_{TSP1}^W$	$\overline{\pi}_{TSP1}^W$
$E[\pi_{TSP2}^{W-X_1X_2}]$	$\overline{\pi}_{TSP2}^W+V_{TSP2}^{W-II}$	$\overline{\pi}_{TSP2}^W$	$\overline{\pi}_{TSP2}^W+V_{TSP2}^{W-NI}$	$\overline{\pi}_{TSP2}^W$
$E[\pi_{OTP}^{W-X_1X_2}]$	$\overline{\pi}_{OTP}^W+F_{OTP}^W+V_{OTP}^{W-II}$	$\overline{\pi}_{OTP}^W+F_{OTP}^W+V_{OTP}^{W-IN}$	$\overline{\pi}_{OTP}^W+F_{OTP}^W+V_{OTP}^{W-NI}$	$\overline{\pi}_{OTP}^W+F_{OTP}^W$

demand and the OTP's and the TSP1′s prices. The TSP2 considers $E[a]$, $E[p_1^{W-X_1N}]$ and $E[p_2^{W-X_1N}(w_2^{W-X_1N}(p_1^{W-X_1N}))]$ in making wholesale price decision under $W-X_1N$. Hence, the TSP2′s expected profits under $W-X_1N$ strategy are as follows:

$$E\left[\pi_{TSP2}^{W-X_1N}\right]=\frac{w_2^{W-X_1N}}{1+\gamma}\left(E[a]-\frac{1}{1-\gamma}E\left[p_2^{W-X_1N}\left(w_2^{W-X_1N}\left(p_1^{W-X_1N}\right)\right]+\frac{\gamma}{1-\gamma}E\left[p_1^{W-X_1N}\right]\right)\right. \tag{14}$$

Under $W-X_1I$ strategy, the TSP2′s expected market demand as well as the tourism service price 1 and 2 are $E[a|Y]$, $E[p_1^{W-X_1I}|Y]$ and $E[p_2^{W-X_1I}(w_2^{W-X_1I}(p_1^{W-X_1I}))|Y]$, respectively. In this case, the TSP2′s expected profits under $W-X_1I$ strategy are given by:

$$E\left[\pi_{TSP2}^{W-X_1I}|Y\right]=\frac{w_2^{W-X_1I}}{1+\gamma}\left(E[a|Y]-\frac{1}{1-\gamma}E\left[p_2^{W-X_1I}\left(w_2^{W-X_1I},p_1^{W-X_1I}\right)|Y\right]+\frac{\gamma}{1-\gamma}E\left[p_1^{W-X_1I}|Y\right]\right) \tag{15}$$

Theorem 3. *The equilibrium results under the wholesale introduction strategy are shown in Table 4.*
where $g_1=\frac{1-\gamma}{8-3\gamma^2-\lambda\gamma^2}$, $g_2=3\gamma+\lambda\gamma+4$, $g_3=\gamma(4+3\gamma)$, $g_4=2-\lambda\gamma-\lambda\gamma^2+\gamma$, $g_5=(3+\lambda)\gamma^2+(2\lambda+6)\gamma+4$, $g_6=(-2\gamma^4-5\gamma^3-3\gamma^2)\lambda^2+(\gamma^3+13\gamma^2+28\gamma+16)\lambda+\gamma^2+4\gamma+4$, $g_7=(-9\gamma^4-20\gamma^3-12\gamma^2)\lambda^2+(-6\gamma^4+4\gamma^3+68\gamma^2+112\gamma+64)\lambda-9\gamma^4$ - $+52\gamma^2+16\gamma-48$ and $g_8=(-\gamma^3-2\gamma^2)\lambda^2+(-6\gamma^3-4\gamma^2+16\gamma+32)\lambda-9\gamma^3+6\gamma^2+32\gamma$. $\overline{\pi}_{TSP1}^W=\frac{(1-\lambda)(4+3\gamma)^2g_1^2\overline{a}^2}{1-\gamma^2}$, $\overline{\pi}_{TSP2}^W=\frac{2g_1^2g_4^2\overline{a}^2}{1-\gamma^2}$ and $\overline{\pi}_{OTP}^W=\frac{g_6g_1^2\overline{a}^2}{1-\gamma^2}$. $V_{TSP1}^{W-II}=\frac{(1-\lambda)(4+3\gamma)^2g_1^2\rho^2\Delta^2\overline{a}^2}{1-\gamma^2}$ and $V_{TSP1}^{W-IN}=\frac{4(1-\lambda)(2+\gamma)^2g_1^2\rho^2\Delta^2\overline{a}^2}{1-\gamma^2}$. $V_{TSP2}^{W-II}=\frac{2g_1^2g_4^2\rho^2\Delta^2\overline{a}^2}{1-\gamma^2}$ and $V_{TSP2}^{W-NI}=\frac{(1-\gamma)\rho^2\Delta^2\overline{a}^2}{8(1+\gamma)}$. $F_{OTP}^W=\frac{(1-\gamma)\rho^2\Delta^2\overline{a}^2}{4(1+\gamma)}$, $V_{OTP}^{W-II}=\frac{g_7g_1^2\rho^2\Delta^2\overline{a}^2}{4(1-\gamma^2)}$, $V_{OTP}^{W-IN}=\frac{(2+\gamma)g_8g_1^2\rho^2\Delta^2\overline{a}^2}{4(1-\gamma^2)}$ and $V_{OTP}^{W-NI}=-\frac{3(1-\gamma)\rho^2\Delta^2\overline{a}^2}{16(1+\gamma)}$.

Theorem 3 demonstrates that under the wholesale introduction strategy, demand information sharing positively affects the TSP1′s and the TSP2′s decisions, and the positive effect is strongest under $W-II$ strategy (i.e., $\partial p_1^{W-II}/\partial E[a|Y]>\partial p_1^{W-IN}/\partial E[a|Y]$ and $\partial w_2^{W-II}/\partial E[a|Y]>\partial w_2^{W-NI}/\partial E[a|Y]$). Moreover, since the positive impact of the TSP1′s and the TSP2′s decisions on the OTP's price decision, the OTP sets the price more responsively (i.e., $\partial p_2^{W-II}/\partial E[a|Y]>max\{\partial p_2^{W-IN}/\partial E[a|Y], \partial p_2^{W-NI}/\partial E[a|Y]\}>\partial p_2^{W-NN}/\partial E[a|Y]>0$). Besides, under $W-NN$ strategy, the uninformed TSP1 and TSP2 only obtain the deterministic profits, and the OTP's expected profits include the deterministic profits and the forecast profits due to its forecast behavior. Under the other three strategies, the information sharing profits are also gained by the OTP and the informed TSPs.

5. Results and insights

Section 4 has derived the equilibrium results under different strategies. On this basis, this section first examines the OTP's optimal demand information sharing strategy under different introduction strategies, then investigates the OTP's optimal introduction strategy, and finally explores the Pareto improvement of the OTP's strategy choices.

5.1. *The OTP's optimal demand information sharing strategy under different introduction strategies*

Comparing the OTP's information sharing profits, Proposition 1 is derived.

Proposition 1. *The OTP's optimal demand information sharing strategy under different introduction strategies is as follows:*

(1) Under the no introduction strategy: The OTP shares with the TSP1 (i.e., $V_{OTP}^{B-I}>0$).
(2) Under the agency introduction strategy: The OTP shares with the TSP1 and the TSP2 (i.e., $V_{OTP}^{A-II}>V_{OTP}^{A-IN}=V_{OTP}^{A-NI}>0$).
(3) Under the wholesale introduction strategy: When $0<\lambda<min\{\lambda_1, 1\}$, the OTP only shares with the TSP1 (i.e., $V_{OTP}^{W-IN}>V_{OTP}^{W-II}>V_{OTP}^{W-NI}$). When $\lambda_1<\lambda<1$, the OTP shares with the TSP1 and the TSP2 simultaneously (i.e., $V_{OTP}^{W-II}>V_{OTP}^{W-IN}>V_{OTP}^{W-NI}$).

where λ_1 is presented in Appendix.

Propositions 1(1) and 1(2) state that under the no introduction and the agency introduction strategies, the OTP always shares with the agency cooperating TSPs. The rationale is that under the no introduction strategy, the informed TSP1 can adjust price accordingly based on the demand signal, and thus the TSP1 is better off with the information sharing. Then, due to the positive correlation of interests between the OTP and the TSP1 under the no introduction strategy, information sharing is also beneficial to the OTP. For the agency introduction strategy, according to Theorem 2, information sharing has the strongest positive impact on the TSP1′s and the TSP2′s price decisions under $A-II$ strategy; therefore, the TSP1 and the TSP2 benefit most from the information sharing under $A-II$ strategy. Accordingly, the OTP is willing to share with the TSP1 and the TSP2 simultaneously because of the consistency of interests under the agency introduction strategy.

Proposition 1(3) indicates that under the wholesale introduction strategy, if the commission rate is high, the OTP shares with both the agency cooperating TSP1 and the wholesale cooperating TSP2 simultaneously. Information sharing with the agency cooperating TSP1 improves the accuracy of the TSP1′s price decision, and thus the OTP, whose interests are aligned with the TSP1, is better off. However, information sharing with the wholesale cooperating TSP2 induces the TSP2 to adjust the wholesale price more responsively, resulting in severe double marginalization; therefore, the OTP suffers a loss. Specifically, under $W-NI$ strategy, as information sharing exacerbates double marginalization, the OTP is not willing to only share with the wholesale cooperating TSP2. Moreover, compared with $W-IN$ strategy, although $W-II$ strategy hurts the OTP due to the information sharing with the TSP2, it also mitigates the adverse effect of uncertain demand on the TSP1 further, which benefits the OTP more from the TSP1′s price

Table 5
The OTP's optimal introduction strategy.

Regions	Conditions		Optimal strategy
R1	$0 < \lambda < min\{\lambda_2,\ \lambda_3\}$		$W-IN$
R2	$0 < \gamma < \gamma_1$ and $\lambda_2 < \lambda < min\{\lambda_4,\ 1\}$	$0 < \rho\Delta < \tau_1$	$A-II$
		$\tau_1 < \rho\Delta < 1$	$W-IN$
R3	$\gamma_1 < \gamma < 1$ and $\lambda_3 < \lambda < min\{\lambda_5,\ 1\}$	$0 < \rho\Delta < \tau_2$	$B-I$
		$\tau_2 < \rho\Delta < 1$	$W-IN$
R4	$\lambda_4 < \lambda < 1$		$A-II$
R5	$\lambda_5 < \lambda < 1$		$B-I$

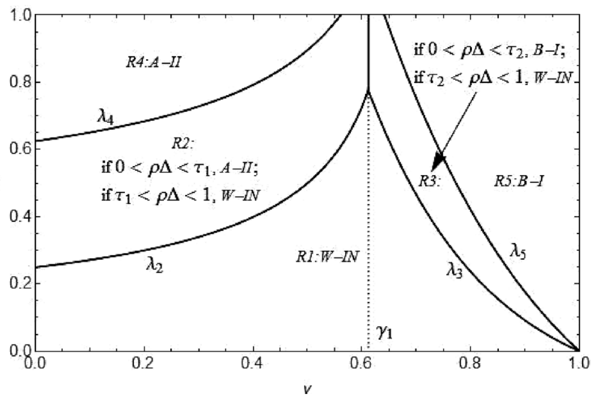

Fig. 3. The OTP's introduction choice.

adjustment. As a result, when $0 < \lambda < min\{\lambda_1, 1\}$, the benefit from the TSP1′s price adjustment does not make up the loss from the TSP2′s decision adjustment under $W-II$ strategy, and thus $W-IN$ strategy dominates $W-II$ strategy. However, when $\lambda_1 < \lambda < 1$, since the negative impact of double marginalization is weakened under $W-II$ strategy (i.e., $\partial^2 w_2^{W-II}/\partial E[a|Y]\partial\lambda < 0$), the combined effect of the TSP1′s and the TSP2′s decision adjustments under $W-II$ strategy dominates the positive impact of the TSP1′s price adjustment under $W-IN$ strategy. Consequently, $W-II$ strategy is optimal for the OTP.

Proposition 1 provides useful managerial implications. Demand information sharing with the agency cooperating TSP should be actively promoted by the OTP regardless of the introduction strategy. Besides, for the wholesale cooperating TSP, Proposition 1 indicates that the downstream OTP may benefit from the demand information sharing with the wholesale cooperating upstream TSP2. This result is different from Jiang and Hao (2016) and Ha and Zhang (2017). They explore downstream member's information sharing incentive with the single wholesale cooperating upstream member (Ha and Zhang, 2017) or with the competing wholesale cooperating upstream members (Jiang and Hao, 2016), and show that the downstream member will not benefit from the demand information sharing due to the aggravated double marginalization. The reason behind the different results is that Jiang and Hao (2016) and Ha and Zhang (2017) consider the issue of demand information sharing under the wholesale model, while we investigate that under the "agency + wholesale" hybrid model (i.e., the wholesale introduction strategy). Hence, it implies that under the wholesale introduction strategy, the OTP should also actively promote the information sharing with the wholesale cooperating TSP2 under certain conditions.

5.2. The OTP's optimal introduction strategy

Based on Section 5.1, we observe that the OTP always shares with the cooperating TSPs under the no introduction and the agency introduction strategies, but shares with the TSP1 and the TSP2 simultaneously under the wholesale introduction strategy only if $\lambda_1 < \lambda < 1$. Therefore, when $0 < \lambda < min\{\lambda_1, 1\}$, $B-I$, $A-II$ or $W-IN$ strategy can be selected by the OTP. Moreover, when $\lambda_1 < \lambda < 1$, $B-I$, $A-II$ or $W-II$ strategy can be chosen by the OTP. For presentation purposes, we define $\rho\Delta$ as the forecast variability. Besides, let the expected profits related to $\rho\Delta$ be the non-deterministic profits.

Proposition 2.. *The OTP's optimal introduction strategy is presented in Table 5.*
where γ_1, λ_2, λ_3, λ_4, λ_5, τ_1 and τ_2 are shown in Appendix.

Proposition 2 presents the OTP's optimal introduction strategy, as shown in Fig. 3. On the one hand, as the competition intensity increases, the negative effect of price competition on the OTP is intensified, and thus the OTP increasingly prefers not to introduce the competing TSP2. Besides, the increase in commission rate enhances the OTP's commission income, so the OTP has a stronger motivation to choose the agency model for sales. As a result, the OTP's introduction choice is driven by the positive impact of the commission rate and the negative impact of the competition intensity.

Specifically, in R1, the positive impact of the commission rate on the OTP under the no introduction and the agency introduction strategies is weak. However, under the wholesale introduction strategy, the OTP alleviates the negative impact of price competition by adjusting the price decision and also avoids the low profitability caused by the low commission rate. Therefore, the OTP prefers $W-IN$ strategy in R1. As the commission rate increases (i.e., in R2 and R3), the OTP's profitability advantage gradually weakens under $W-IN$ strategy. In R2 and R3, under $W-IN$ strategy, the OTP's deterministic profits advantage is lost, but the OTP still maintains its non-deterministic profits advantage because the demand information sharing can effectively reduce the negative impact of demand fluctuation on the OTP's and the TSP1′s decisions. Hence, only if the forecast variability is high, the positive impact of the non-deterministic profits is stronger, and $W-IN$ strategy generates higher profits for the OTP in R2 and R3. Otherwise, the OTP prefers $A-II$ strategy in R2 ($B-I$strategy in R3) due to the weak (strong) negative effect of price competition. As the commission rate increases further, the OTP's deterministic profits disadvantage under $W-IN$ strategy is more significant in R4, and thus the OTP chooses $A-II$ strategy. Moreover, in R5, the increase in commission rate intensifies the negative impact of price competition on the OTP under the wholesale introduction strategy, and thus $B-I$ strategy is optimal for the OTP.

Note that in R1, due to the moderating role of the OTP on the price competition under the wholesale introduction strategy, the OTP still has an incentive to introduce competing TSP even if the price competition is fierce. This reminds the OTP that for the tourism services with low commission rate (e.g., airline tickets), the OTP should actively choose the wholesale introduction strategy to improve performance even though the tourism services market is very competitive. Besides, in R2, R3 and R5, even though the commission rate is high under the agency model, introducing competing TSP using the agency model may still hurt the OTP because of the moderating effect of forecast variability or the strong negative impact of price competition. Hence, it suggests that for the tourism services with high commission rate (e.g., hotels), the OTP should carefully adopt the agency introduction strategy.

By analyzing the influence of competing TSP introduction on the TSP1's price decision, we derive Corollary 1.

Corollary 1. *When the OTP chooses $W-IN$ strategy and $Y = l$, if $\tau_3 < \rho\Delta < 1$ in R1, or if $max\{\tau_1, \tau_3\} < \rho\Delta < 1$ in R2, or if $max\{\tau_2, \tau_3\} < \rho\Delta < 1$ in R3, then $p_1^{W-IN} > p_1^{B-I}$.*
where τ_3 is presented in Appendix.

Corollary 1 indicates that when the OTP introduces the competing TSP2, the TSP1 may increase the tourism service price. The rationale is that when the demand signal is low (e.g., $Y = l$), the informed TSP1 will decrease the price under $W-IN$ strategy, but the reduction is less than that under $B-I$ strategy since introducing the competing TSP2 weakens

Table 6
The TSC's optimal strategy.

Regions	Conditions		Optimal strategy
R6	$max\{0,\lambda_9\} < \lambda < 1$		$A-II$
R7	$max\{0,\lambda_8\} < \lambda < min\{\lambda_9, 1\}$	$0 < \rho\Delta < \tau_4$	$A-II$
		$\tau_4 < \rho\Delta < 1$	$W-IN$
R8	$max\{0,\lambda_7\} < \lambda < min\{\lambda_8, 1\}$		$W-IN$
R9	$max\{0,\lambda_{10}\} < \lambda < min\{\lambda_7,\lambda_{11}\}and\lambda_{11} < \lambda < min\{\lambda_7, \lambda_{10}, 1\}$		$W-II$
R10	$0 < \lambda < min\{\lambda_{10},\lambda_{11}\}andmax\{\lambda_{10},\lambda_{11}\} < \lambda < 1$		$B-I$

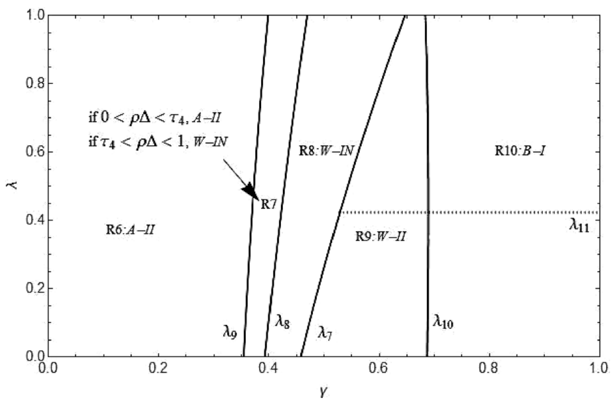

Fig. 4. The TSC's optimal strategy.

Table 7
The Pareto improvement regions and the corresponding transfer payment contracts.

Cases	Conditions	ZB	ZA	Contracts	Pareto type
Case 1	R2-5 and$0 < \rho\Delta < \tau_1$	$A-II$	$W-II$	$TP1$or $TP2$	Introduction strategy (M Pareto)
Case 2	R3-1 and $0 < \rho\Delta < \tau_2$; R5-1; R5-2	$B-I$	$W-IN$	$TP3$	
Case 3	R1-5; R3-3 and$\tau_2 < \rho\Delta < 1$	$W-IN$	$B-I$	$TP2$	
Case 4	R1-4; R2-5 and $\tau_1 < \rho\Delta < 1$; R3-2 and$\tau_2 < \rho\Delta < 1$	$W-IN$	$W-II$	$TP1$	Information sharing strategy (X Pareto)
Case 5	R1-1; R1-2 and $\tau_4 < \rho\Delta < 1$; R2-1 and $\tau_1 < \rho\Delta < 1$; R2-2 and$\tau_1 < \rho\Delta < \tau_4$	$W-IN$	$A-II$	$TP3$	Introduction strategy and information sharing strategy (MX Pareto)
Case 6	R2-3 and $\tau_4 < \rho\Delta < \tau_1$; R2-4 and $0 < \rho\Delta < \tau_1$; R4-2 and $\tau_4 < \rho\Delta < 1$; R4-3	$A-II$	$W-IN$	$TP1$or$TP2$	
Case 7	R3-2 and$0 < \rho\Delta < \tau_2$	$B-I$	$W-II$	$TP3$	

where T_{TSP1} and T_{TSP2} satisfy $T_{TSP1} + T_{TSP2} \geqslant |\Lambda_{OTP}|$ and $0 \leqslant T_{TSPi} \leqslant |\Lambda_{TSPi}|$ under $TP1$ contract. Under $TP2$ contract, T_{TSP1} and T_{TSP2} satisfy $T_{TSP1} - T_{TSP2} \geqslant |\Lambda_{OTP}|$, $T_{TSP2} \geqslant |\Lambda_{TSP2}|$ and $0 < T_{TSP1} \leqslant |\Lambda_{TSP1}|$. Under $TP3$ contract, T_{TSP1} and T_{TSP2} satisfy $T_{TSP2} - T_{TSP1} \geqslant |\Lambda_{OTP}|$, $T_{TSP1} \geqslant |\Lambda_{TSP1}|$ and $0 < T_{TSP2} \leqslant |\Lambda_{TSP2}|$. Besides, the shaded regions of Fig. 5 show the Pareto improvement regions, and Appendix presents the parameter ranges of regions in this proposition.

the positive effect of the information sharing on the TSP1′s price decision. Hence, when $\rho\Delta$ is high, the effect of the forecast variability on the TSP1′s price decision is significant, resulting in a stronger price reduction of the TSP1 under $B-I$ strategy than under $W-IN$ strategy, namely,

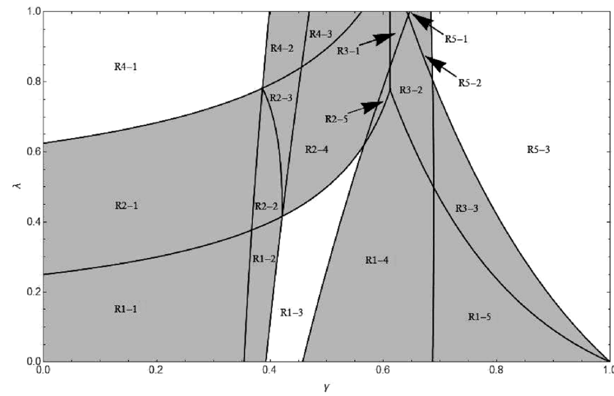

Fig. 5. The Pareto improvement regions.

$p_1^{W-IN} > p_1^{B-I}$. Intuitively, after introducing the competing TSP2, the TSP1 may need to decrease its price to maintain a competitive advantage. However, Corollary 1 suggests that when the OTP introduces the competing TSP2, the TSP1 should consider the introduction strategy, the demand signal and the forecast variability in adjusting the price, and price cuts may hurt the TSP1 under certain conditions.

5.3. The Pareto improvement of the OTP's strategies

Sections 5.1 and 5.2 have investigated the OTP's optimal demand information sharing and introduction strategies. However, the OTP's strategy choices may be inconsistent with the TSP1 and the TSP2, and also may induce the TSC to suffer a loss; therefore, it is necessary to further investigate the Pareto improvement of the OTP's strategies. In this section, we first analyze the TSP1′s, the TSP2′s and the TSC's strategy choices which consist of the demand information sharing strategy and introduction strategy, then identify the Pareto improvement regions and design the contract to achieve Pareto improvement.

5.3.1. The TSP1′s and the TSP2′s optimal strategies

We obtain the following Proposition 3 by analyzing the TSP1′s and the TSP2′s expected profits.

Proposition 3. *The TSP1′s and the TSP2′s optimal strategies are given below:*

(1) The TSP1: $B-I$ strategy is always optimal.
(2) The TSP2: When $0 < \lambda < \lambda_6$, $A-II$ strategy is optimal. When $\lambda_6 < \lambda < 1$, $W-II$ strategy is optimal.

where λ_6 is presented in Appendix.

Proposition 3 reveals the TSP1′s and the TSP2′s optimal strategies. Both the TSP1 and the TSP2 are willing to gain the demand information since the more accurate pricing decisions can be made. Moreover, the more TSPs obtain demand information, the stronger the positive impact of the information sharing on the informed TSPs. Therefore, both the TSP1 and the TSP2 prefer the OTP to share with all the cooperating TSPs (i.e., $B-I$, $A-II$ or $W-II$ strategy). As for the introduction strategy, the introduction of the competing TSP2 will lead to channel competition, which weakens the TSP1′s profitability, and thus the TSP1 always prefers $B-I$ strategy. However, the TSP2 would like to partner with the OTP because of the positive gains. In addition, as the commission rate increases, the TSP2′s commission profits under $A-II$ strategy gradually decreases; therefore, the TSP2′s preferred strategy changes from $A-II$ strategy to $W-II$ strategy.

5.3.2. The TSC's optimal strategy

The following proposition characterizes the TSC's strategy choices.

Proposition 4. *The TSC's optimal strategy is summarized in* Table 6.

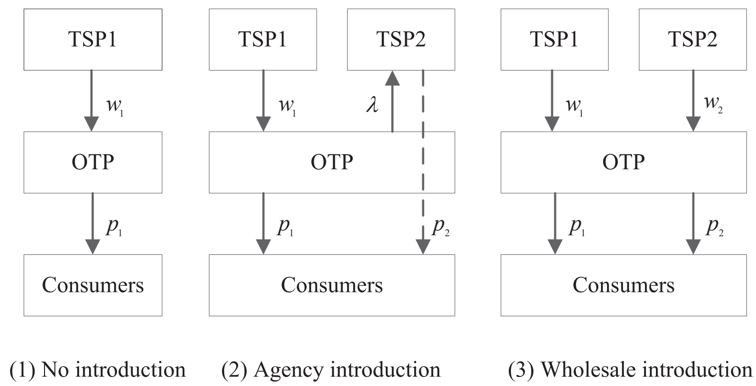

Fig. 6. Channel structures when the wholesale model is applied with the TSP1.

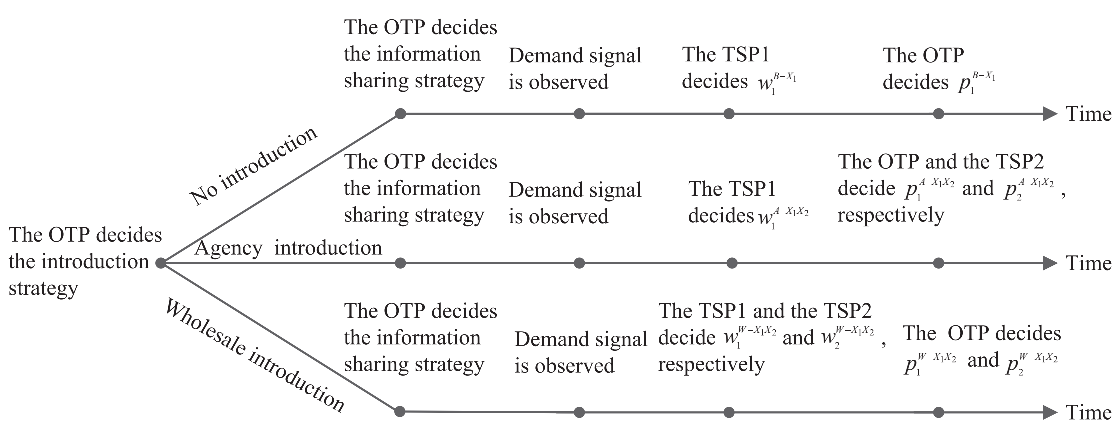

Fig. 7. The sequence of events when the wholesale model is applied with the TSP1.

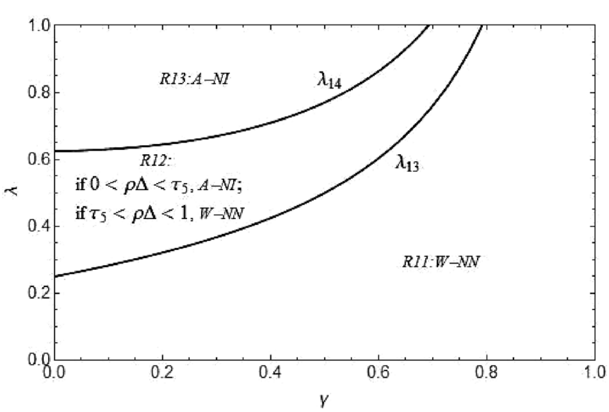

Fig. 8. The OTP's optimal introduction strategy when the wholesale model is applied with the TSP1.

where λ_7, λ_8, λ_9, λ_{10}, λ_{11} and τ_4 are shown in Appendix.

Proposition 4 states that as the competition intensity increases, the TSC's optimal strategy switches from $A-II$ strategy to $W-IN$ strategy, then to $W-II$ strategy, and finally to $B-I$ strategy, as illustrated in Fig. 4. The TSC's expected profits are affected by the OTP's strategy choices. For the OTP's information sharing, it is beneficial to the TSC under the no introduction and the agency introduction strategies because the more responsive pricing decisions can be made by the TSPs. Under the wholesale introduction strategy, the combined effect of the TSP1′s and the TSP2′s decision adjustments on the TSC under $W-II$ strategy dominates the positive effect of the TSP1′s price adjustment on the TSC under $W-IN$ strategy only if in R9 and R10; therefore, the TSC benefits more under $W-II$ strategy in R9 and R10. Otherwise, $W-IN$ strategy is more profitable for the TSC in R6, R7 and R8. Accordingly, $B-I$, $A-II$ or $W-IN$ strategy can be chosen by the TSC in R6, R7 and R8. Moreover, in R9 and R10, $B-I$, $A-II$ or $W-II$ strategy can be selected by the TSC.

Specifically, $A-II$ strategy mitigates the negative impact of double marginalization but leads to fierce price competition in comparison with $W-IN$ strategy or $W-II$ strategy. Hence, $A-II$ strategy is a dominant strategy for the TSC in R6 because price competition is limited. However, as the competition intensity increases, the TSC's profitability under $A-II$ strategy gradually weakens. In R7, compared with $W-IN$ strategy, $A-II$ strategy generates higher deterministic profits (i.e., $\overline{\pi}_{TSC}^{A} > \overline{\pi}_{TSC}^{W}$), but leads to lower non-deterministic profits (i.e., $V_{TSC}^{A-II} < F_{TSC}^{W} + V_{TSC}^{W-IN}$). As a result, only if the forecast variability is low, the positive impact of the deterministic profits on the TSC is stronger than that of the non-deterministic profits, and $A-II$ strategy dominates $W-IN$ strategy in R7. As price competition intensifies (i.e., in R8), the TSC's deterministic profits advantage is also lost, and thus $W-IN$ strategy is more profitable for the TSC. In R9, since the positive effect of demand information sharing on the TSC is stronger under $W-II$ strategy than under $W-IN$ strategy, the TSC benefits more under $W-II$ strategy. Additionally, no matter what cooperation model the OTP adopts to introduce the competing TSP in R10, the TSC's loss is significant due to the fierce price competition. Consequently, $B-I$ strategy is optimal in R10.

5.3.3. The Pareto improvement regions and strategies for the OTP's strategy choices

According to Propositions 2, 3 and 4, we observe that the TSC may suffer a loss under the OTP's optimal strategies in some regions. By analyzing the regions where the strategy choices of the OTP and the TSC are inconsistent, the Pareto improvement regions can be identified. Besides, we also design a transfer payment contract that the OTP charges or subsidizes the TSPs a fixed fee T to realize a Pareto improvement. To simplify the expressions, ZB and ZA strategies are defined as the OTP's optimal strategy before and after the Pareto improvement, respectively. Let $\Lambda_j = \pi_j^{ZA} - \pi_j^{ZB}$ as the expected profits difference of j under ZA and ZA strategies. Moreover, we define $TP1$ as the transfer payment contract that the OTP charges the TSP1 and the TSP2 a fixed fee T_{TSP1} and T_{TSP2}, respectively. $TP2$ is the transfer payment contract that the OTP charges the TSP1 a fixed fee T_{TSP1} and subsidizes the TSP2 a fixed fee T_{TSP2}. Let $TP3$ as the transfer payment contract that the OTP subsidizes the TSP1 a fixed fee T_{TSP1} and charges the TSP2 a fixed fee T_{TSP2}.

Proposition 5. *The Pareto improvement regions and the corresponding transfer payment contracts are summarized in* Table 7.

Proposition 5 states that three Pareto improvement regions exist. Specifically, in M Pareto regions, the OTP's information sharing strategy is beneficial to the TSC, whereas the introduction strategy causes significant losses for the TSPs, thereby leading to the inefficiency of the TSC. Besides, in X Pareto regions, the introduction choices of the OTP and the TSC are consistent, while the OTP's information sharing strategy does not make the TSC achieve the highest information sharing profits. In MX Pareto regions, both the introduction and information sharing strategies for the OTP and the TSC are different.

Proposition 5 also indicates that there are three types of transfer payment contracts that enable the OTP to achieve Pareto improvement. If both the TSP1 and the TSP2 benefit from ZB strategy, then the OTP can charge both the TSP1 and the TSP2 a fixed fee to realize a Pareto improvement, namely, $TP1$ contract. The fixed fee should make up for the OTP's losses caused by strategy adjustment, and it cannot be higher than each TSP's incremental profits. If ZB strategy is only profitable for the TSP1 (TSP2), then the OTP can charge the TSP1 (TSP2) a fixed fee and compensate the TSP2 (TSP1) a fixed fee, namely, $TP2$ contract ($TP3$ contract). Under $TP2$ contract ($TP3$ contract), the net fixed fee obtained by the OTP and the compensation for the TSP2 (TSP1) should cover their respective losses, and the fixed fee charged to the TSP1 (TSP2) cannot exceed its benefits from adopting a more profitable strategy. Note that in cases 1 and 6, ZB strategy benefits the TSP1, but may be beneficial or harmful to the TSP2. Accordingly, in these two cases, the OTP should adopt $TP1$ contract if the TSP2 benefits from ZB strategy. Otherwise, the OTP should implement $TP2$ contract.

The results in Proposition 5 are in line with the cooperation practice between the OTP and the TSPs. In practice, a fixed service fee is charged by some OTPs to the cooperating TSPs. For example, Fliggy.com, an online travel platform in China, charges a RMB15000 yearly service fee to some hotels. Another Chinese online travel platform, trip.jd.com, charges vacation TSPs a RMB500 service fee every month. The service fee charged by the above OTPs plays the role of the $TP1$ contract. However, Proposition 5 also suggests that the OTP cannot only charge a fixed fee to the TSPs, and the compensation for some TSPs is also needed under certain conditions.

6. Extension: The wholesale model is applied with the TSP1

In the base model, considering that the agency model is usually the initial and the dominant form of the cooperation model between the OTP and the TSPs, we assume that the OTP cooperates with the incumbent TSP1 via the agency model. However, the wholesale model may be applied with the incumbent TSP1. Hence, to better reflect the reality and offer more insights for the OTP and the TSPs, we explore the OTP's optimal strategy when the wholesale model is implemented between them in this section. Specifically, this section first examines the OTP's optimal demand information sharing strategy. Then, the introduction choice of the OTP is investigated.

When the wholesale model is applied with the TSP1, the corresponding channel structures under different introduction strategies are as follows.

Under the no introduction strategy, the TSP1 first decides the wholesale price $w_1^{B-X_1}$, and then the OTP sets the tourism service price $p_1^{B-X_1}$. Under the agency introduction strategy, the TSP1 sets the wholesale price $w_1^{A-X_1X_2}$ first. Then, the OTP and the TSP2 choose the tourism service price $p_1^{A-X_1X_2}$ and $p_2^{A-X_1X_2}$, respectively. Under the wholesale introduction strategy, the TSP1 and the TSP2 determine the wholesale price $w_1^{W-X_1X_2}$ and $w_2^{W-X_1X_2}$, respectively. Then, the OTP chooses the tourism service price $p_1^{W-X_1X_2}$ and $p_2^{W-X_1X_2}$. Fig. 7 shows the sequence of events.

Using a method similar to the base model, the equilibrium results under different introduction strategies are derived. The specific results are shown in Appendix. We can obtain the following Proposition 6 by analyzing the OTP's information sharing profits.

Proposition 6. *When the wholesale model is applied with the TSP1, the OTP's optimal demand information sharing strategy under different introduction strategies is as follows:*

(1) Under the no introduction strategy: The OTP does not share with the TSP1.
(2) Under the agency introduction strategy: When $0 < \lambda < min\{\lambda_1, 1\}$, the OTP only shares with the TSP2. When $\lambda_1 < \lambda < 1$, the OTP shares with the TSP1 and the TSP2 simultaneously.
(3) Under the wholesale introduction strategy: The OTP does not share with the TSP1 and the TSP2.

Propositions 6(1) and 6(3) indicate that under the no introduction and the wholesale introduction strategies, the OTP is not willing to share with the wholesale cooperating TSPs. The reason is that the informed TSPs would make more responsive wholesale price decision based on the demand signal, which exacerbates double marginalization, and thus information sharing is harmful to the OTP.

Proposition 6(2) states that under the agency introduction strategy, the OTP may share with both the wholesale cooperating TSP1 and the agency cooperating TSP2, which is similar to that of Proposition 1(3). When sharing with the wholesale cooperating TSP1, the OTP will be worse off due to severe double marginalization. However, information sharing with the agency cooperating TSP2 is beneficial to the OTP because of the consistency of interests. Therefore, the OTP's information sharing strategy choice is driven by the negative effect of the information sharing with wholesale cooperating TSP1 and the positive effect of the information sharing with the agency cooperating TSP2. Specifically, when the commission rate is high, since the negative impact of double marginalization is reduced under $A-II$ strategy, the combined effect of information sharing with the wholesale cooperating TSP1 and the agency cooperating TSP2 under $A-II$ strategy dominates the positive impact of the information sharing with the agency cooperating TSP2 under $A-NI$ strategy. Consequently, the OTP prefers $A-II$ strategy. Otherwise, $A-NI$ strategy is optimal for the OTP.

Consistent with Proposition 1, Proposition 6 suggests that when the wholesale model is applied with the incumbent TSP1, demand information sharing with the agency cooperating TSP should be actively promoted by the OTP, but that with the wholesale cooperating TSP should be cautiously made according to the introduction strategy.

Proposition 7. *When the wholesale model is applied with the TSP1, the OTP's optimal introduction strategy is given below:*

(1) When $0 < \lambda < min\{\lambda_{13}, 1\}$, $W-NN$ strategy is optimal.
(2) When $\lambda_{13} < \lambda < min\{\lambda_{14}, 1\}$, there exists a threshold τ_5, such that if $0 < \rho\Delta < \tau_5$, then $A-NI$ strategy is optimal; if $\tau_5 < \rho\Delta < 1$, then $W-NN$ strategy is optimal.
(3) When $\lambda_{14} < \lambda < 1$, $A-NI$ strategy is optimal.

where λ_{13}, λ_{14} and τ_5 are shown in Appendix.

Proposition 7 reveals the OTP's introduction choice when the wholesale model is applied with the incumbent TSP1, as illustrated in Fig. 8. On the one hand, compared with the no introduction strategy, although the wholesale introduction strategy leads to channel competition, the OTP alleviates the negative impact of channel competition by adjusting tourism services' prices and also obtains lower wholesale price due to upstream competition. As a result, $W-NN$ strategy always dominates $B-N$ strategy. However, the wholesale introduction strategy does not always dominate the agency introduction strategy for the OTP. This is because that as the commission rate increases, the OTP's commission profits under the agency introduction strategy gradually increases, and thus the OTP increasingly prefers the agency introduction strategy. Consequently, when the commission rate is high (i.e., in R13), $A-NI$ strategy is optimal for the OTP. Otherwise, the OTP prefers $W-NN$ strategy when the commission rate is low (i.e., in R11). As for the region with a moderate commission rate (i.e., in R12), in contrast to the wholesale introduction strategy, the agency introduction strategy can induce the OTP to obtain the deterministic profits advantage, but the non-deterministic profits advantage is lost because of the low value of information sharing. Hence, only if the forecast variability is low, the deterministic profits' positive impact on the OTP is stronger, and $A-NI$ strategy generates higher profits for the OTP in R12. Otherwise, the OTP prefers $W-NN$ strategy in R12.

Different from the base model, when adopting the wholesale model to cooperate with the TSP1, the OTP is always willing to introduce the competing TSP2 regardless of the competition intensity. In addition, similar to the base model, Proposition 7 also suggests that if the wholesale model is applied with the incumbent TSP1, then the OTP should take into consideration the competition intensity, the commission rate and the forecast variability when choosing the introduction strategy.

7. Conclusions

In recent years, whether and how to introduce the competing TSP is a critical issue for lots of OTPs to expand markets and improve profitability. Moreover, in the presence of uncertain demand, whether to share demand information with the TSPs is also a strategic concern for these OTPs when introducing the competing TSP. Hence, this paper explores the introduction and information sharing strategies for the OTP considering the competing TSP introduction under demand uncertainty. Through a game model, the OTP's optimal introduction and information sharing strategies are derived, and then the Pareto improvement of the OTP's strategy choices are identified.

The conclusions are as follows. (1) Under the no introduction and the agency introduction strategies, the OTP is always willing to share with the agency cooperating TSP1 or TSP2. In comparison, under the wholesale introduction strategy, the OTP shares with both the agency cooperating TSP1 and the wholesale cooperating TSP2 only if the commission rate is high. (2) Both the competition intensity and the commission rate affect the introduction choice of the OTP, while the demand fluctuation and demand forecast accuracy also critically influence choice under certain conditions. Note that the OTP may introduce the competing TSP even if the price competition is fierce. Moreover, the agency introduction strategy may lead to the loss of the OTP even though the commission rate is high. Furthermore, the incumbent TSP1 may increase the tourism service price when the OTP adopts wholesale introduction strategy. (3) Information sharing may be harmful to the TSC under different introduction strategies. As the competition intensity improves, the TSC's introduction choice switches from the agency introduction strategy to the wholesale introduction strategy and then to the no introduction strategy. (4) The Pareto improvement regions of the OTP's introduction strategy or (and) demand information sharing strategy exist, and the OTP can design three types of contracts to achieve Pareto improvement. Particularly, in some Pareto improvement regions, the compensation for some TSPs is also needed. (5) When the wholesale model is applied with the incumbent TSP1, the OTP always has an incentive to introduce the competing TSP2, no matter how fierce the price competition is.

The above results provide guidance for the OTP's and the TSPs' introduction and demand information sharing decisions. First, no matter what introduction strategy is adopted, the OTP should actively promote the demand information sharing with the agency cooperating TSP, and that of the wholesale cooperating TSP should also be encouraged under certain conditions. Second, when deciding the introduction strategy, the OTP cannot just care about the competition intensity, and the commission rate and the forecast variability should also be taken into consideration. Note that for the tourism services with low commission rate, the OTP should actively adopt the wholesale introduction strategy to introduce the competing TSP2 even if the price competition is fierce. While for the tourism services with high commission rate, the OTP should carefully adopt the agency introduction strategy. Third, the strategy choices of the OTP may not always be consistent with those of the TSPs, and the TSPs can encourage the OTP to implement contract to achieve Pareto improvement. Fourth, when the wholesale model is applied with the incumbent TSP1, the OTP should actively introduce the competing TSP2 regardless of the competition intensity.

CRediT authorship contribution statement

Yi Liu: Conceptualization, Methodology, Validation, Formal analysis, Writing - original draft. **Xumei Zhang:** Conceptualization, Methodology, Supervision, Project administration, Funding acquisition. **Haiyue Zhang:** Conceptualization, Methodology, Formal analysis. **Xiaoyu Zha:** Conceptualization, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

A.1 Proof of Theorem 1

Under $B-N$ strategy, we can obtain $\partial^2 E[\pi^{B-N}_{TSP1}]/\partial^2 p_1^{B-N} = -2 + 2\lambda < 0$, and thus $E[\pi^{B-N}_{TSP1}]$ is concave in p_1^{B-N}. By solving $\partial E[\pi^{B-N}_{TSP1}]/\partial p_1^{B-N} = (1-\lambda)(a - 2p_1^{B-N}) = 0$, we get $p_1^{B-N} = \overline{a}/2$. Following the similar argument, we can derive $p_1^{B-I} = E[a|Y]/2$ under $B-I$ strategy. Finally, substituting the optimal tourism service price into the Eqs. (5), (6) and (7), we can obtain $E[\pi_{TSP1}^{B-X_1}]$ and $E[\pi_{OTP}^{B-X_1}]$.

A.2 Proof of Theorem 2

Under $A-II$ strategy, since $\partial^2 E[\pi_{TSPi}^{A-II}]/\partial^2 p_i^{A-II} = -2(1-\lambda)/(1+\gamma)(1-\gamma) < 0$, we gain that $E[\pi_{TSPi}^{A-II}]$ is concave in p_i^{A-II}. Thus, by solving $\partial E[\pi_{TSP1}^{A-II}]/\partial p_1^{A-II} = 0$ and $\partial E[\pi_{TSP2}^{A-II}]/\partial p_2^{A-II} = 0$, we get p_1^{A-II} and p_2^{A-II}. The proof of equilibriums under the other three strategies can use similar methods. Finally, substituting the optimal tourism service prices into the Eqs. (8), (9) and (10), we obtain $E[\pi_{OTP}^{A-X_1X_2}]$, $E[\pi_{TSP1}^{A-X_1X_2}]$ and $E[\pi_{TSP2}^{A-X_1X_2}]$, respectively.

A.3 Proof of Theorem 3

We first prove the equilibrium under $W-II$ strategy. For the TSP1, its decision is based on the expected OTP's tourism service price since it cannot observe w_2^{W-II}. From $\partial^2 E[\pi_{TSP1}^{W-II}]/\partial^2 p_1^{W-II} = -2(1-\lambda)/(1+\gamma)(1-\gamma) < 0$, we get that $E[\pi_{TSP1}^{W-II}]$ is concave in p_1^{W-II}. Then, we get $p_1^{W-II}(p_2^{W-II}) = ((1-\gamma)E[a|Y] + \gamma p_2^{W-II})/2$. For the OTP, its decision is influenced by the TSP1's and the TSP2's decisions. Since $\partial^2 E[\pi_{OTP}^{W-II}]/\partial^2 p_2^{W-II} = -2/(1+\gamma)(1-\gamma) < 0$, $E[\pi_{OTP}^{W-II}]$ is concave in p_2^{W-II}. Then, we gain $p_2^{W-II}(p_1^{W-II}, w_2^{W-II}) = ((1-\gamma)E[a|Y] + (1+\lambda)\gamma p_1^{W-II} + w_2^{W-II})/2$. Substituting it into the TSP2's expected profits, we can easily get that $E[\pi_{TSP2}^{W-II}]$ is concave in w_2^{W-II} (i.e., $\partial^2 E[\pi_{TSP2}^{W-II}]/\partial^2 w_2^{W-II} = -1/(1+\gamma)(1-\gamma) < 0$). Then, we can derive that the optimal reaction function of w_2^{W-II} is $w_2^{W-II}(p_1^{W-II}) = ((1-\gamma)E[a|Y] + (1-\lambda)\gamma p_1^{W-II})/2$. Substituting $w_2^{W-II}(p_1^{W-II})$ into $p_2^{W-II}(p_1^{W-II}, w_2^{W-II})$, we further derive $p_2^{W-II}(p_1^{W-II}) = (3(1-\gamma)E[a|Y] + (3+\lambda)\gamma p_1^{W-II})/4$. By solving $p_1^{W-II}(p_2^{W-II})$ and $p_2^{W-II}(p_1^{W-II})$ simultaneously, we can derive optimal decisions of $p_1^{W-X_1X_2}$ and $p_2^{W-X_1X_2}$. Moreover, substituting $p_1^{W-X_1X_2}$ into $w_2^{W-II}(p_1^{W-II})$, we can derive optimal $w_2^{W-X_1X_2}$. In a similar way, we can prove the equilibriums under the other three strategies. Finally, substituting $p_1^{W-X_1X_2}$, $p_2^{W-X_1X_2}$ and $w_2^{W-X_1X_2}$ into the TSC members' expected profits, we derive $E[\pi_{TSP1}^{W-X_1X_2}]$, $E[\pi_{TSP2}^{W-X_1X_2}]$ and $E[\pi_{OTP}^{W-X_1X_2}]$, respectively.

A.4 Proof of Proposition 1

Firstly, under the no introduction strategy, we have $V_{OTP}^{B-I} = \lambda\rho^2\Delta^2\overline{a}^2/4 > 0$.

Next, under the agency introduction strategy, we get $V_{OTP}^{A-II} = 2(1-\gamma)\lambda\rho^2\Delta^2\overline{a}^2/(1+\gamma)(2-\gamma)^2$ and $V_{OTP}^{A-IN} = V_{OTP}^{A-NI} = (1-\gamma)\lambda\rho^2\Delta^2\overline{a}^2/4(1+\gamma)$ from Theorem 2. We can show that $V_{OTP}^{A-II} - V_{OTP}^{A-IN} = \lambda(1-\gamma)(4+4\gamma-\gamma^2)\rho^2\Delta^2\overline{a}^2/4(1+\gamma)(2-\gamma)^2$. The sign of $V_{OTP}^{A-II} - V_{OTP}^{A-IN}$ is depends on the sign of $4+4\gamma-\gamma^2$. Since $4+4\gamma-\gamma^2 > 0$ always holds, we derive $V_{OTP}^{A-II} > V_{OTP}^{A-IN} = V_{OTP}^{A-NI}$.

Finally, under the wholesale introduction strategy, we can easily get $V_{OTP}^{W-NI} = -3(1-\gamma)\rho^2\Delta^2\overline{a}^2/16(1+\gamma) < 0$ and $V_{OTP}^{W-IN} = (2+\gamma)g_8g_1^2\rho^2\Delta^2\overline{a}^2/4(1-\gamma^2) > 0$. Thus, the OTP has no incentive to only share with the TSP2, but may only share with the TSP1. Besides, we can show that $V_{OTP}^{W-II} - V_{OTP}^{W-IN} = H_1(\lambda,\gamma)(1-\gamma)\rho^2\Delta^2\overline{a}^2/(1+\gamma)(8-(3+\lambda)\gamma^2)^2$, where $H_1(\lambda,\gamma) = (-2\gamma^4 - 4\gamma^3 - 2\gamma^2)\lambda^2 + (5\gamma^3 + 15\gamma^2 + 12\gamma)\lambda + 3\gamma^3 + 2\gamma^2 - 12\gamma - 12$. The sign of $V_{OTP}^{W-II} - V_{OTP}^{W-IN}$ depends on the sign of $H_1(\lambda,\eta)$. There is a unique λ_1 making $H_1(\lambda,\gamma) = 0$. Then, when $0 < \lambda < min\{\lambda_1, 1\}$, we have $H_1(\lambda,\gamma) < 0 \Leftrightarrow V_{OTP}^{W-IN} > V_{OTP}^{W-II}$. When $\lambda_1 < \lambda < 1$, we have $H_1(\lambda,\gamma) > 0 \Leftrightarrow V_{OTP}^{W-IN} < V_{OTP}^{W-II}$.

A.5 Proof of Proposition 2

The OTP's expected profits consist of the deterministic profits and non-deterministic profits.

Firstly, we compare the deterministic profits. Comparing $\overline{\pi}_{OTP}^A$ and $\overline{\pi}_{OTP}^B$, we derive that $\overline{\pi}_{OTP}^A - \overline{\pi}_{OTP}^B = \lambda(4-8\gamma+3\gamma^2-\gamma^3)\overline{a}^2/4(1+\gamma)(2-\gamma)^2$. The sign of $\overline{\pi}_{OTP}^A - \overline{\pi}_{OTP}^B$ depends on the sign of $4-8\gamma+3\gamma^2-\gamma^3$. There is a unique γ_1 making $4-8\gamma+3\gamma^2-\gamma^3 = 0$. We can easily get that if $0 < \gamma < \gamma_1$, then $\overline{\pi}_{OTP}^A > \overline{\pi}_{OTP}^B$. If $\gamma_1 < \gamma < 1$, then $\overline{\pi}_{OTP}^A < \overline{\pi}_{OTP}^B$. Thus, when $0 < \gamma < \gamma_1$, we need to further compare $\overline{\pi}_{OTP}^W$ and $\overline{\pi}_{OTP}^A$. We can show that $\overline{\pi}_{OTP}^W - \overline{\pi}_{OTP}^A = H_2(\lambda,\gamma)(1-\gamma)a^2/(1+\gamma)(2-\gamma)^2(3\gamma^2+\lambda\gamma^2-8)^2$, where $H_2(\lambda,\gamma) = -2\gamma^4\lambda^3 + (-3\gamma^4 + 20\gamma^2 - 8\gamma^3 - 2\gamma^6 + 3\gamma^5)\lambda^2 + (\gamma^5 + 48\gamma - 64 - 9\gamma^4 - 20\gamma^3 + 52\gamma^2)\lambda + 16 - 8\gamma^2 + \gamma^4$. The sign of $\overline{\pi}_{OTP}^W - \overline{\pi}_{OTP}^A$ depends on the sign of $H_2(\lambda,\eta)$. There exists a unique λ_2 making $H_2(\lambda,\eta) = 0$. We can easily verify that $\overline{\pi}_{OTP}^W > \overline{\pi}_{OTP}^A$ if $0 < \gamma < \gamma_1$ and $0 < \lambda < \lambda_2$, and $\overline{\pi}_{OTP}^W < \overline{\pi}_{OTP}^A$ if $0 < \gamma < \gamma_1$ and $\lambda_2 < \lambda < 1$. Besides, when $\gamma_1 < \gamma < 1$, we need to further compare $\overline{\pi}_{OTP}^W$ and $\overline{\pi}_{OTP}^B$. We can show that $\overline{\pi}_{OTP}^W - \overline{\pi}_{OTP}^B = H_3(\lambda,\gamma)\overline{a}^2/4(1+\gamma)(3\gamma^2+\lambda\gamma^2-8)^2$, where $H_3(\lambda,\gamma) = (-\gamma^4-\gamma^5)\lambda^3 + (4\gamma^2 + 6\gamma^4 + 8\gamma^3 + 2\gamma^5)\lambda^2 + (-9\gamma^5 - 13\gamma^4 - 16\gamma - 12\gamma^2)\lambda + 16 - 12\gamma^2 - 4\gamma^3$. The sign of $\overline{\pi}_{OTP}^W - \overline{\pi}_{OTP}^B$ depends on the sign of $H_3(\lambda,\eta)$. There is a unique λ_3 that satisfies $H_3(\lambda,\gamma) = 0$. If $\gamma_1 < \gamma < 1$ and $0 < \lambda < \lambda_3$, then $\overline{\pi}_{OTP}^W > \overline{\pi}_{OTP}^B$. If $\gamma_1 < \gamma < 1$ and $\lambda_3 < \lambda < 1$, then $\overline{\pi}_{OTP}^W < \overline{\pi}_{OTP}^B$.

Next, we compare the OTP's non-deterministic profits under different strategies. We first compare V_{OTP}^{A-II} and V_{OTP}^{B-I}. We can show that $V_{OTP}^{A-II} - V_{OTP}^{B-I} = \lambda(4-8\gamma+3\gamma^2-\gamma^3)\rho^2\Delta^2\overline{a}^2/4(1+\gamma)(2-\gamma)^2$. The sign of $V_{OTP}^{A-II} - V_{OTP}^{B-I}$ is the same as the sign of $\overline{\pi}_{OTP}^A - \overline{\pi}_{OTP}^B$. That is, if $0 < \gamma < \gamma_1$, then $V_{OTP}^{A-II} > V_{OTP}^{B-I}$. If $\gamma_1 < \gamma < 1$, then $V_{OTP}^{A-II} < V_{OTP}^{B-I}$. Hence, when $0 < \gamma < \gamma_1$, we need to further compare V_{OTP}^{A-II} and $F_{OTP}^W + V_{OTP}^{W-IN}$. we can easily get that $F_{OTP}^W + V_{OTP}^{W-IN} - V_{OTP}^{A-II} > 0$ always holds. Moreover, if $\gamma_1 < \gamma < 1$ and $\lambda_1 < \lambda < 1$, then we need to compare V_{OTP}^{B-I} and $F_{OTP}^W + V_{OTP}^{W-II}$. If $\gamma_1 < \gamma < 1$ and $0 < \lambda < min\{\lambda_1, 1\}$, then we need to compare V_{OTP}^{B-I} and $F_{OTP}^W + V_{OTP}^{W-IN}$. Specifically, when $\gamma_1 < \gamma < 1$ and $\lambda_1 < \lambda < 1$, we can easily show that $F_{OTP}^W + V_{OTP}^{W-II} - V_{OTP}^{B-I} < 0$ always holds. However, when $\gamma_1 < \gamma < 1$ and $0 < \lambda < min\{\lambda_1, 1\}$, we get $F_{OTP}^W + V_{OTP}^{W-IN} - V_{OTP}^{B-I} = H_4(\lambda,\gamma)\rho^2\Delta^2\overline{a}^2/4(1+\gamma)(3\gamma^2+\lambda\gamma^2-8)^2$, where $H_4(\lambda,\gamma) = (-\gamma^4-\gamma^5)\lambda^3 + (12\gamma^2 + 16\gamma^3 - 6\gamma^5 - 2\gamma^4)\lambda^2 + (40\gamma^3 - 24\gamma^2 - 9\gamma^5 + 7\gamma^4 - 64\gamma)\lambda + 64 - 68\gamma^2 - 8\gamma^3 + 12\gamma^4$. The sign of $F_{OTP}^W + V_{OTP}^{W-IN} - V_{OTP}^{B-I}$ depends on the sign of $H_4(\lambda,\eta)$. There is a unique $\widetilde{\lambda}$ making $H_4(\lambda,\gamma) = 0$. If $\gamma_1 < \gamma < 1$ and $0 < \lambda < min\{\widetilde{\lambda}, 1\}$, then $F_{OTP}^W + V_{OTP}^{W-IN} > V_{OTP}^{B-I}$. If $\widetilde{\lambda} < \lambda < min\{\lambda_1, 1\}$, then $F_{OTP}^W + V_{OTP}^{W-IN} < V_{OTP}^{B-I}$.

Finally, based on the above results, we obtain that $\overline{\pi}_{OTP}^W > max\backslash\{\overline{\pi}_{OTP}^A, \overline{\pi}_{OTP}^B\}$ and $F_{OTP}^W + V_{OTP}^{W-IN} > max\{V_{OTP}^{B-I}, V_{OTP}^{A-II}\}$ in R1, so the OTP prefers $W-IN$ strategy. When $0 < \gamma < \gamma_1$ and $\lambda_2 < \lambda < 1$ (i.e., in R2 and R4), the OTP always has an incentive to introduce the TSP2. Moreover, compared $A-II$ strategy with $W-IN$ strategy, we derive $\overline{\pi}_{OTP}^W < \overline{\pi}_{OTP}^A$ and $F_{OTP}^W + V_{OTP}^{W-IN} > V_{OTP}^{A-II}$. Therefore, the OTP's optimal strategy also depends on the forecast variability $\rho\Delta$. We can easily get that $\partial(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}])/\partial(\rho\Delta)^2 > 0$. When $(\rho\Delta)^2 = 0$, we get $min(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}])\langle 0$. When $(\rho\Delta)^2 = 1$, there is a unique λ_4 that satisfies $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}]) = 0$. If $\lambda_4 < \lambda < 1$, then $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}])\langle 0$. Otherwise, $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}])\rangle 0$. As a result, when $\lambda_4 < \lambda < 1$ (i.e., in R4), we get $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}])\langle 0$, so the OTP prefers $A-II$ strategy. When $0 < \gamma < \gamma_1$ and $\lambda_2 < \lambda < min\{\lambda_4, 1\}$ (i.e., in R2), we derive that $min(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}])\langle 0$ and $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}])\rangle 0$. Obviously, in R2, there is a unique τ_1 that satisfies $E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{A-II}] = 0$. Hence, in R2, if $0 < \rho\Delta < \tau_1$, then $A-II$ strategy is profitable. Otherwise, the OTP prefers $W-IN$ strategy. When $\gamma_1 < \gamma < 1$ and $\lambda_3 < \lambda < 1$ (i.e., in R3 and R5), the OTP has no incentive to adopt $A-II$ strategy. Comparing $B-I$ strategy with $W-IN$ strategy, we get $\overline{\pi}_{OTP}^{W} < \overline{\pi}_{OTP}^{A}$ and $F_{OTP}^{W} + V_{OTP}^{W-IN} > V_{OTP}^{A-II}$. Besides, we get that $\partial(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{B-I}])/\partial(\rho\Delta)^2 > 0$. When $(\rho\Delta)^2 = 0$, we can derive $min(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{B-I}]) < 0$. When $(\rho\Delta)^2 = 1$, there is a unique λ_5 that satisfies $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{B-I}]) = 0$. If $\lambda_5 < \lambda < 1$ (i.e., in R5), then $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{B-I}]) < 0$. That is, the OTP prefers $B-I$ strategy in R5. If $\gamma_1 < \gamma < 1$ and $\lambda_3 < \lambda < min\{\lambda_5, 1\}$ (i.e., in R3), then $max(E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{B-I}])\rangle 0$. Accordingly, there is a unique τ_2 that satisfies $E[\pi_{OTP}^{W-IN}] - E[\pi_{OTP}^{B-I}] = 0$ in R3. Then, when $0 < \rho\Delta < \tau_2$, the OTP prefers $B-I$ strategy in R3. Otherwise, $W-IN$ strategy is optimal.

A.6 Proof of Corollary 1

Firstly, we compare p_1^{A-II} and p_1^{B-I}. We can show that $p_1^{A-II} - p_1^{B-I} = -\gamma E[a|Y]/2(2-\gamma) < 0$ always holds.

Then, we compare p_1^{W-IN} and p_1^{B-I}. Specifically, when $Y = h$, we can easily get $p_1^{W-IN} - p_1^{B-I} = \overline{a}\gamma(\lambda\gamma - 3\gamma - 2 + (\lambda\gamma - \gamma - 4)\rho\Delta)/2(8 - (3+\lambda)\gamma^2) < 0$, and thus $p_1^{W-IN} < p_1^{B-I}$. When $Y = l$, we can derive that $p_1^{W-IN} - p_1^{B-I} = \overline{a}\gamma(\lambda\gamma - 3\gamma - 2 + (-\lambda\gamma + \gamma + 4)\rho\Delta)/2(8 - (3+\lambda)\gamma^2)$. There is a unique τ_3 that satisfies $\lambda\gamma - 3\gamma - 2 + (-\lambda\gamma + \gamma + 4)\rho\Delta = 0$. Then, when $0 < \rho\Delta < \tau_3$, $(\lambda\gamma - 3\gamma - 2 + (\lambda\gamma - \gamma - 4)\rho\Delta) < 0 \Leftrightarrow p_1^{W-IN} < p_1^{B-I}$. Otherwise, when $\tau_3 < \rho\Delta < 1$, $(\lambda\gamma - 3\gamma - 2 + (\lambda\gamma - \gamma - 4)\rho\Delta) > 0 \Leftrightarrow p_1^{W-IN} > p_1^{B-I}$. Note that in R2 (R3), the OTP prefers $W-IN$ strategy only if $\tau_1 < \rho\Delta < 1$ ($\tau_2 < \rho\Delta < 1$). Thus, we prove that if $\tau_3 < \rho\Delta < 1$ in R1, or if $max\{\tau_1, \tau_3\} < \rho\Delta < 1$ in R2, or if $max\{\tau_2, \tau_3\} < \rho\Delta < 1$ in R3, then $p_1^{W-IN} > p_1^{B-I}$.

A.7 Proof of Proposition 3

Firstly, we can easily verify that $V_{TSP1}^{B-I} > V_{TSP1}^{B-N}$, $V_{TSP1}^{A-II} > max\{V_{TSP1}^{A-IN}, V_{TSP1}^{A-NN}\}$, $V_{TSP2}^{A-II} > max\{V_{TSP2}^{A-NI}, V_{TSP2}^{A-NN}\}$, $V_{TSP1}^{W-II} > max\{V_{TSP1}^{W-IN}, V_{TSP1}^{W-NN}\}$ and $V_{TSP2}^{W-II} > max\{V_{TSP2}^{W-NI}, V_{TSP2}^{W-NN}\}$. That is, the TSP1 and the TSP2 prefer the OTP to share with all the cooperating TSPs.

Next, we prove the TSP1′s and the TSP2′s optimal introduction strategies. As for the TSP1, we can get that $E[\pi_{TSP1}^{A-I}] - E[\pi_{TSP1}^{AW-II}] = \frac{\gamma(1-\lambda)((\gamma^3+\gamma^4)\lambda^2 + (-16\gamma + 6\gamma^3 - 16\gamma^2 + 6\gamma^4)\lambda + 9\gamma^3 + 9\gamma^4 - 12\gamma^2 + 12\gamma + 32)\overline{a}^2(1+\rho^2\Delta^2)}{4(1+\gamma)(3\gamma^2+\lambda\gamma^2-8)^2}$. We obtain that $E[\pi_{TSP1}^{A-I}] - E[\pi_{TSP1}^{AW-II}] > 0$always holds. Then, we can show that $E[\pi_{TSP1}^{W-II}] - E[\pi_{TSP1}^{A-II}] = \frac{\gamma(1-\gamma)(1-\lambda)(2+\lambda\gamma)(16-\lambda\gamma^2-6\gamma^2+2\gamma)\overline{a}^2(1+\rho^2\Delta^2)}{(1+\gamma)(3\gamma^2+\lambda\gamma^2-8)^2(2-\gamma)^2}$. We can easily get that $E[\pi_{TSP1}^{W-II}] - E[\pi_{TSP1}^{A-II}] > 0$ also holds. Hence, the TSP1 always prefers $B-I$ strategy. For the TSP2, we can show that $E[\pi_{TSP2}^{AW-II}] - E[\pi_{TSP2}^{A-II}] = \frac{(1-\gamma)[\gamma^4\lambda^3 + (-\gamma^4 + 8\gamma^3 + 2\gamma^6 - 4\gamma^5 - 8\gamma^2)\lambda^2 + (-48\gamma^2 - 32\gamma - 4\gamma^5 + 7\gamma^4 + 24\gamma^3 + 64)\lambda - 32 + 32\gamma^2 + 9\gamma^4 - 12\gamma^2 - 7\gamma^4]\overline{a}^2(1+\rho^2\Delta^2)}{(1+\gamma)(3\gamma^2+\lambda\gamma^2-8)^2(2-\gamma)^2}$. There is a unique λ_6 that satisfies $E[\pi_{TSP2}^{W-II}] - E[\pi_{TSP2}^{A-II}] = 0$. If $\lambda_6 < \lambda < 1$, then $E[\pi_{TSP2}^{W-II}] > E[\pi_{TSP2}^{A-II}]$. Otherwise, $E[\pi_{TSP2}^{W-II}] < E[\pi_{TSP2}^{A-II}]$.

A.8 Proof of Proposition 4

Firstly, we explore the TSC's information sharing preference. According to Section 4, we obtain $V_{TSC}^{B-I} > V_{TSC}^{B-N}$ and $V_{TSC}^{A-II} > V_{TSC}^{A-NI} = V_{TSC}^{A-IN} > V_{TSC}^{A-NN}$, and thus information sharing is beneficial to the TSC under the no introduction and the agency introduction strategies. Under the wholesale introduction strategy, we only need to compare V_{TSC}^{W-II} and V_{TSC}^{W-IN}. We get that $V_{TSC}^{W-II} - V_{TSC}^{W-IN} = H_5(\lambda,\gamma)(1-\gamma)\rho^2\Delta^2\overline{a}^2/(1+\gamma)(8-(3+\lambda)\gamma^2)^2$, where $H_5(\lambda, \gamma) = (-2\gamma^2 - 4\gamma + \gamma^3)\lambda - 4 + 4\gamma + 9\gamma^2 + 3\gamma^3$. There is a unique λ_7 that satisfies $H_5(\lambda,\gamma) = 0$. If $0 < \lambda < min\{\lambda_7, 1\}$, then $H_5(\lambda,\gamma) > 0 \Leftrightarrow V_{TSC}^{W-II} > V_{TSC}^{W-IN}$. If $max\{0, \lambda_7\} < \lambda < 1$, then $H_5(\lambda,\gamma) < 0 \Leftrightarrow V_{TSC}^{W-II} < V_{TSC}^{W-IN}$. As a result, when $max\{0, \lambda_7\} < \lambda < 1$, we need to compare the TSC's expected profits under $B-I$, $A-II$ and $W-IN$ strategies. When $0 < \lambda < min\{\lambda_7, 1\}$, we need to compare its expected profits under $B-I$, $A-II$ and $W-II$ strategies.

Then, we first prove the TSC's optimal strategy when $max\{0, \lambda_7\} < \lambda < 1$. Comparing $E[\pi_{TSC}^{W-IN}]$ and $E[\pi_{TSC}^{B-I}]$, we can easily get $\overline{\pi}_{TSC}^{W} > \overline{\pi}_{TSC}^{B}$ and $F_{TSC}^{W} + V_{TSC}^{W-IN} > V_{TSC}^{B-I}$, and thus $W-IN$ strategy dominates $B-I$ strategy. Then, we compare $E[\pi_{TSC}^{W-IN}]$ and $E[\pi_{TSC}^{A-II}]$. As for the deterministic profits, we can show that $\overline{\pi}_{TSC}^{W} - \overline{\pi}_{TSC}^{A} = H_6(\lambda,\gamma)(1-\gamma)(\lambda\gamma+2)\overline{a}^2/(1+\gamma)(2-\gamma)^2(3\gamma^2+\lambda\gamma^2-8)^2$, where $H_6(\lambda,\gamma) = (-\gamma^4 + \gamma^3 - 4\gamma)\lambda - 8 + 16\gamma + 14\gamma^2 - 6\gamma^3 - 3\gamma^4$. There is a unique λ_8 making $H_6(\lambda,\gamma) = 0$. If $max\{0, \lambda_7\} < \lambda < min\{\lambda_8, 1\}$, then $H_6(\lambda,\gamma) > 0 \Leftrightarrow \overline{\pi}_{TSC}^{W} > \overline{\pi}_{TSC}^{A}$. If $max\{0, \lambda_8\} < \lambda < 1$, then $H_6(\lambda,\gamma) < 0 \Leftrightarrow \overline{\pi}_{TSC}^{W} < \overline{\pi}_{TSC}^{A}$. Besides, comparing non-deterministic profits, we can derive $F_{TSC}^{W} + V_{TSC}^{W-IN} - V_{TSC}^{A-II} = H_7(\lambda,\gamma)(1-\gamma)(1+\lambda)\gamma^2\rho^2\Delta^2\overline{a}^2/(1+\gamma)(2-\gamma)^2(8-(3+\lambda)\gamma^2)^2$, where $H_7(\lambda,\gamma) = (-\gamma^3 + \gamma^2 - 4)\lambda + 12 + 8\gamma - 3\gamma^2 - 3\gamma^3$. We can easily get that $H_7(\lambda,\gamma) > 0$ always holds, and thus $F_{TSC}^{W} + V_{TSC}^{W-IN} > V_{TSC}^{A-II}$ if $max\{0, \lambda_7\} < \lambda < 1$. Combining the results of the deterministic and non-deterministic profits comparisons, we get $\overline{\pi}_{TSC}^{W} > \overline{\pi}_{TSC}^{A}$ and $F_{TSC}^{W} + V_{TSC}^{W-IN} > V_{TSC}^{A-II}$ when $max\{0, \lambda_7\} < \lambda < min\{\lambda_8, 1\}$ (i.e., in R8), and thus $W-IN$ strategy is optimal for the TSC. When $max\{0, \lambda_8\} < \lambda < 1$, we derive that $\overline{\pi}_{TSC}^{W} < \overline{\pi}_{TSC}^{A}$ and $F_{TSC}^{W} + V_{TSC}^{W-IN} > V_{TSC}^{A-II}$. Hence, the TSC's optimal strategy also depends on the forecast variability. We can show that $\partial(E[\pi_{TSC}^{W-IN}] - E[\pi_{TSC}^{A-II}])/\partial(\rho\Delta)^2 > 0$. When $(\rho\Delta)^2 = 0$, we get $min(E[\pi_{TSC}^{W-IN}] - E[\pi_{TSC}^{A-II}])\langle 0$. When $(\rho\Delta)^2 = 1$, there is a unique λ_9 making $max(E[\pi_{TSC}^{W-IN}] - E[\pi_{TSC}^{B-I}]) = 0$. If $max\{0, \lambda_9\} < \lambda < 1$ (i.e., in R6), then $max(E[\pi_{TSC}^{W-IN}] - E[\pi_{TSC}^{B-I}])\langle 0$, and thus $A-II$ strategy is optimal. If $max\{0, \lambda_8\} < \lambda < min\{\lambda_8, 1\}$ (i.e., in R7), then $max(E[\pi_{TSC}^{W-IN}] - E[\pi_{TSC}^{B-I}])\rangle 0$. Therefore, in R7, there is a unique τ_4 satisfies $E[\pi_{TSC}^{W-IN}] - E[\pi_{TSC}^{A-II}] = 0$. Then, when $0 < \rho\Delta < \tau_4$, $A-II$ strategy is optimal in R7. Otherwise, $W-IN$ strategy is profitable in R7.

Finally, when $0 < \lambda < min\{\lambda_7, 1\}$, we can easily derive that $E[\pi_{TSC}^{A-II}] < max\{E[\pi_{TSC}^{W-II}], E[\pi_{TSC}^{B-I}]\}$, and thus $A-II$ strategy is always the suboptimal strategy when $0 < \lambda < min\{\lambda_7, 1\}$. Then, comparing $E[\pi_{TSC}^{W-IN}]$ and $E[\pi_{TSC}^{B-I}]$, we can show that $E[\pi_{TSC}^{W-IN}] - E[\pi_{TSC}^{B-I}] = H_8(\lambda, \gamma)(1 + (\rho\Delta)^2)\overline{a}^2/4(1+\gamma)(3\gamma^2 + \lambda\gamma^2 - 8)^2$, where $H_8(\lambda,\gamma) = (-4\gamma^2 + 3\gamma^4 - \gamma^5)\lambda^2 + (36\gamma^3 + 6\gamma^4 - 16\gamma - 6\gamma^5)\lambda + 48 - 32\gamma - 48\gamma^2 - 9\gamma^4 - 9\gamma^5$. There exist unique λ_{10} and $\lambda_{11} \approx 0.424$ that satisfy $H_8(\lambda,\gamma) = 0$ and $H_8(\lambda_{11}, \gamma \approx 0.689) = 0$, respectively. Then, when $max\{0, \lambda_{10}\} < \lambda < min\{\lambda_7, \lambda_{11}\}$ and $\lambda_{11} < \lambda < min\{\lambda_7, \lambda_{10}, 1\}$ (i.e., in R9), $H_8(\lambda,\gamma) > 0 \Leftrightarrow E[\pi_{TSC}^{W-IN}] > E[\pi_{TSC}^{B-I}]$, so $W-IN$ strategy is optimal for the TSC. When $0 < \lambda < min\{\lambda_{10}, \lambda_{11}\}$ and $max\{\lambda_{10}, \lambda_{11}\} < \lambda < 1$ (i.e., in R10), $H_8(\lambda,\gamma) < 0 \Leftrightarrow E[\pi_{TSC}^{W-IN}] < E[\pi_{TSC}^{B-I}]$. That is, $B-I$ strategy is optimal in R10.

A.9 Proof of Proposition 5

Baesd on Propositions 2, 3 and 4, the Pareto improvement regions and the corresponding transfer payment contracts can be easily derived.

Besides, the parameter ranges of regions in Proposition 5 are shown as follows. $R1-1 \in \{\lambda | max\{0, \lambda_9\} < \lambda < \lambda_2\}$, $R1-2 \in \{\lambda | max\{0, \lambda_8\} < \lambda < min\{\lambda_2, \lambda_9\}\}$, $R1-3 \in \{\lambda | max\{0, \lambda_7\} < \lambda < min\{\lambda_2, \lambda_8\}\}$, $R1-4 \in \{\lambda | max\{0, \lambda_{10}\} < \lambda < min\{\lambda_7, \lambda_{11}\}$ *and* $\lambda_{11} < \lambda < min\{\lambda_2, \lambda_3, \lambda_7, \lambda_{10}\}\}$ and $R1-5 \in \{\lambda | 0 < \lambda < min\{\lambda_3, \lambda_{10}, \lambda_{11}\}$ *and* $max\{\lambda_{10}, \lambda_{11}\} < \lambda < \lambda_3\}$. $R2-1 \in \{\lambda | max\{\lambda_2, \lambda_9\} < \lambda < \lambda_4\}$, $R2-2 \in \{\lambda | \lambda_2 < \lambda < min\{\lambda_9, \lambda_{12}\}\}$, $R2-3 \in \{\lambda | max\{\lambda_8, \lambda_{12}\} < \lambda < \lambda_4\}$, $R2-4 \in \{(\gamma, \lambda) | \gamma_2 < \gamma < \gamma_1, max\{\lambda_2, \lambda_7\} < \lambda < min\{\lambda_4, \lambda_8, 1\}\}$ and $R2-5 \in \{(\gamma, \lambda) | \gamma_3 < \gamma < \gamma_1, \lambda_2 < \lambda < \lambda_7\}$.$R3-1 \in \{(\gamma, \lambda) | \gamma_1 < \gamma < \gamma_5, \lambda_7 < \lambda < min\{\lambda_5, 1\}\}$, $R3-2 \in \{(\gamma, \lambda) | \gamma_1 < \gamma < \gamma_4, \lambda_3 < \lambda < min\{\lambda_5, \lambda_7, \lambda_{10}\}\}$ and $R3-3 \in \{\lambda | max\{\lambda_3, \lambda_{10}\} < \lambda < \lambda_5\}$. $R4-1 \in \{\lambda | max\{\lambda_4, \lambda_9\} < \lambda < 1\}$, $R4-2 \in \{\lambda | max\{\lambda_4, \lambda_8\} < \lambda < min\{\lambda_9, 1\}\}$ and $R4-3 \in \{\lambda | \lambda_4 < \lambda < min\{\lambda_8, 1\}\}$. $R5-1 \in \{\lambda | max\{\lambda_5, \lambda_7\} < \lambda < 1\}$, $R5-2 \in \{\lambda | \lambda_5 < \lambda < min\{\lambda_7, \lambda_{10}, 1\}\}$ and $R5-3 \in \{\lambda | max\{\lambda_5, \lambda_{10}\} < \lambda < 1\}$. Note that γ_2 satisfies $\lambda_2 = \lambda_8$; γ_3 satisfies $\lambda_2 = \lambda_7$; γ_4 satisfies $\lambda_3 = \lambda_{10}$. Moreover, λ_{12} satisfies $\tau_1 = \tau_4$. Then, $\tau_1 < \tau_4$ in R2-2, and $\tau_1 > \tau_4$ in R2-3.

A.10 Proof of Proposition 6

When the wholesale model is applied with the TSP1, the equilibrium results under different introduction strategies can be derived by using a method same as the base model. The specific results are shown as follows.

The equilibrium results under the no introduction strategy are presented in Table A1.

Table A1
The equilibrium results under the no introduction strategy.

	$B-N$	$B-I$
$p_1^{B-X_1}$	$(\overline{a} + 2E[a\|Y])/4$	$3E[a\|Y]/4$
$w_1^{B-X_1}$	$\overline{a}/2$	$E[a\|Y]/2$
$E[\pi_{TSP1}^{B-X_1}]$	$\overline{\pi}_{TSP1}^B$	$\overline{\pi}_{TSP1}^B + V_{TSP1}^{B-I}$
$E[\pi_{OTP}^{B-X_1}]$	$\overline{\pi}_{OTP}^B + F_{OTP}^B$	$\overline{\pi}_{OTP}^B + F_{OTP}^B + V_{OTP}^{B-I}$

where $\overline{\pi}_{TSP1}^B = \overline{a}^2/8$ and $\overline{\pi}_{OTP}^B = \overline{a}^2/16$. $F_{OTP}^B = \rho^2\Delta^2\overline{a}^2/4$, $V_{TSP1}^{B-I} = \rho^2\Delta^2\overline{a}^2/8$ and $V_{OTP}^{B-I} = -3\rho^2\Delta^2\overline{a}^2/16$.

The equilibrium results under the agency introduction strategy are given in Table A2.

Table A2
The equilibrium results under the agency introduction strategy.

	$A-II$	$A-IN$	$A-NI$	$A-NN$
$p_1^{A-X_1X_2}$	$g_1(g_2+2)E[a\|Y]$	$3(1-\gamma)E[a\|Y]/4$ $+(3+\lambda)g_1g_3\overline{a}/4$	$g_1g_2E[a\|Y] + 2g_1\overline{a}$	$(1-\gamma)E[a\|Y]/2$ $+g_1g_5\overline{a}/2$
$p_2^{A-X_1X_2}$	$(4+3\gamma)g_1E[a\|Y]$	$(4+3\gamma)g_1\overline{a}$	$2(2+\gamma)g_1E[a\|Y]$ $+\gamma g_1\overline{a}$	$(4+3\gamma)g_1\overline{a}$
$w_1^{A-X_1X_2}$	$2g_1g_4E[a\|Y]$	$(1-\gamma)E[a\|Y]/2$ $+(1-\lambda)g_1g_3\overline{a}/2$	$2g_1g_4\overline{a}$	$2g_1g_4\overline{a}$
$E[\pi_{TSP1}^{A-X_1X_2}]$	$\overline{\pi}_{TSP1}^W + V_{TSP1}^{W-II}$	$\overline{\pi}_{TSP1}^W + V_{TSP1}^{W-IN}$	$\overline{\pi}_{TSP1}^W$	$\overline{\pi}_{TSP1}^W$
$E[\pi_{TSP2}^{A-X_1X_2}]$	$\overline{\pi}_{TSP2}^W + V_{TSP2}^{W-II}$	$\overline{\pi}_{TSP2}^W$	$\overline{\pi}_{TSP2}^W + V_{TSP2}^{W-NI}$	$\overline{\pi}_{TSP2}^W$
$E[\pi_{OTP}^{A-X_1X_2}]$	$\overline{\pi}_{OTP}^W + F_{OTP}^W + V_{OTP}^{W-II}$	$\overline{\pi}_{OTP}^W + F_{OTP}^W + V_{OTP}^{W-IN}$	$\overline{\pi}_{OTP}^W + F_{OTP}^W + V_{OTP}^{W-NI}$	$\overline{\pi}_{OTP}^W + F_{OTP}^W$

where $\overline{\pi}_{TSP1}^W = \frac{2g_1^2g_4^2\overline{a}^2}{1-\gamma^2}$, $\overline{\pi}_{TSP2}^W = \frac{(1-\lambda)(4+3\gamma)^2g_1^2\overline{a}^2}{1-\gamma^2}$ and $\overline{\pi}_{OTP}^W = \frac{g_6g_1^2\overline{a}^2}{1-\gamma^2}$. $V_{TSP1}^{W-II} = \frac{2g_1^2g_4^2\rho^2\Delta^2\overline{a}^2}{1-\gamma^2}$ and $V_{TSP1}^{W-IN} = \frac{(1-\gamma)\rho^2\Delta^2\overline{a}^2}{8(1+\gamma)}$. $V_{TSP2}^{W-II} = \frac{(1-\lambda)(4+3\gamma)^2g_1^2\rho^2\Delta^2\overline{a}^2}{1-\gamma^2}$ and $V_{TSP2}^{W-NI} = \frac{4(1-\lambda)(2+\gamma)^2g_1^2\rho^2\Delta^2\overline{a}^2}{1-\gamma^2}$. $F_{OTP}^W = \frac{(1-\gamma)\rho^2\Delta^2\overline{a}^2}{4(1+\gamma)}$, $V_{OTP}^{W-II} = \frac{g_7g_1^2\rho^2\Delta^2\overline{a}^2}{4(1-\gamma^2)}$, $V_{OTP}^{W-IN} = -\frac{3(1-\gamma)\rho^2\Delta^2\overline{a}^2}{16(1+\gamma)}$ and.$V_{OTP}^{W-NI} = \frac{(2+\gamma)g_8g_1^2\rho^2\Delta^2\overline{a}^2}{4(1-\gamma^2)}$. The thresholds g_1, g_2, g_3, g_4, g_5, g_6, g_7 and g_8 are the same as Theorem 3.

The equilibrium results under the wholesale introduction strategy are given in Table A3.

Table A3
The equilibrium results under the wholesale introduction strategy.

	$W-II$	$W-IN$	$W-NI$	$W-NN$
$p_1^{W-X_1X_2}$	$\frac{(3-2\gamma)E[a\|Y]}{2(2-\gamma)}$	$\frac{\gamma(1-\gamma)\overline{a}}{4(2-\gamma)}+\frac{(6-5\gamma+\gamma^2)E[a\|Y]}{4(2-\gamma)}$	$\frac{(1-\gamma)\overline{a}}{2(2-\gamma)}+\frac{E[a\|Y]}{2}$	$\frac{(1-\gamma)\overline{a}}{2(2-\gamma)}+\frac{E[a\|Y]}{2}$
$p_2^{W-X_1X_2}$	$\frac{(3-2\gamma)E[a\|Y]}{2(2-\gamma)}$	$\frac{(1-\gamma)\overline{a}}{2(2-\gamma)}+\frac{E[a\|Y]}{2}$	$\frac{\gamma(1-\gamma)\overline{a}}{4(2-\gamma)}+\frac{(6-5\gamma+\gamma^2)E[a\|Y]}{4(2-\gamma)}$	$\frac{(1-\gamma)\overline{a}}{2(2-\gamma)}+\frac{E[a\|Y]}{2}$
$w_1^{W-X_1X_2}$	$\frac{(1-\gamma)E[a\|Y]}{2-\gamma}$	$\frac{\gamma(1-\gamma)\overline{a}}{2(2-\gamma)}+\frac{(1-\gamma)E[a\|Y]}{2}$	$\frac{(1-\gamma)\overline{a}}{2-\gamma}$	$\frac{(1-\gamma)\overline{a}}{2-\gamma}$
$w_2^{W-X_1X_2}$	$\frac{(1-\gamma)E[a\|Y]}{2-\gamma}$	$\frac{(1-\gamma)\overline{a}}{2-\gamma}$	$\frac{\gamma(1-\gamma)\overline{a}}{2(2-\gamma)}+\frac{(1-\gamma)E[a\|Y]}{2}$	$\frac{(1-\gamma)\overline{a}}{2-\gamma}$
$E[\pi_{TSP1}^{W-X_1X_2}]$	$\overline{\pi}_{TSP1}^{W}+V_{TSP1}^{W-II}$	$\overline{\pi}_{TSP1}^{W}+V_{TSP1}^{W-IN}$	$\overline{\pi}_{TSP1}^{W}$	$\overline{\pi}_{TSP1}^{W}$
$E[\pi_{TSP2}^{W-X_1X_2}]$	$\overline{\pi}_{TSP2}^{W}+V_{TSP2}^{W-II}$	$\overline{\pi}_{TSP2}^{W}$	$\overline{\pi}_{TSP2}^{W}+V_{TSP2}^{W-NI}$	$\overline{\pi}_{TSP2}^{W}$
$E[\pi_{OTP}^{W-X_1X_2}]$	$\overline{\pi}_{OTP}^{W}+F_{OTP}^{W}+V_{OTP}^{W-II}$	$\overline{\pi}_{OTP}^{W}+F_{OTP}^{W}+V_{OTP}^{W-IN}$	$\overline{\pi}_{OTP}^{W}+F_{OTP}^{W}+V_{OTP}^{W-NI}$	$\overline{\pi}_{OTP}^{W}+F_{OTP}^{W}$

where $\overline{\pi}_{TSP1}^{W}=\overline{\pi}_{TSP2}^{W}=\frac{(1-\gamma)\overline{a}^2}{2(1+\gamma)(2-\gamma)^2}$ and $\overline{\pi}_{OTP}^{W}=\frac{\overline{a}^2}{2(1+\gamma)(2-\gamma)^2}$. $V_{TSP1}^{W-II}=V_{TSP2}^{W-II}=\frac{(1-\gamma)\rho^2\Delta^2\overline{a}^2}{2(1+\gamma)(2-\gamma)^2}$ and $V_{TSP1}^{W-IN}=V_{TSP2}^{W-NI}=\frac{(1-\gamma)\rho^2\Delta^2\overline{a}^2}{8(1+\gamma)}$. $F_{OTP}^{W}=\rho^2\Delta^2\overline{a}^2/2(1+\gamma)$, $V_{OTP}^{W-II}=-\frac{(1-\gamma)(3-\gamma)\rho^2\Delta^2\overline{a}^2}{2(1+\gamma)(2-\gamma)^2}$ and $V_{OTP}^{W-IN}=V_{OTP}^{W-NI}=-\frac{3(1-\gamma)\rho^2\Delta^2\overline{a}^2}{16(1+\gamma)}$.

We can easily get that $V_{OTP}^{B-I}-V_{OTP}^{B-N}=-3\rho^2\Delta^2\overline{a}^2/16<0$ under the no introduction strategy. Under the wholesale introduction strategy, we can show that $V_{OTP}^{W-NN}>max\{V_{OTP}^{W-IN},V_{OTP}^{W-NI},V_{OTP}^{W-II}\}$ always holds. While under the agency introduction strategy, we can show that $V_{OTP}^{A-II}-V_{OTP}^{A-NI}=H_1(\lambda,\gamma)(1-\gamma)\rho^2\Delta^2\overline{a}^2/(1+\gamma)(8-(3+\lambda)\gamma^2)^2$, where $H_1(\lambda,\gamma)=(-2\gamma^4-4\gamma^3-2\gamma^2)\lambda^2+(5\gamma^3+15\gamma^2+12\gamma)\lambda+3\gamma^3+2\gamma^2-12\gamma-12$. The sign of $V_{OTP}^{A-II}-V_{OTP}^{A-NI}$ is the same as Proposition 1(3). As a result, when $0<\lambda<min\{\lambda_1,1\}$, $V_{OTP}^{A-II}<V_{OTP}^{A-NI}$. When $\lambda_1<\lambda<1$, $V_{OTP}^{A-II}>V_{OTP}^{A-NI}$.

A.11 Proof of Proposition 7

Firstly, the OTP's expected profits under the no introduction and the wholesale introduction strategies are compared. As for the deterministic profits, we can get that $\overline{\pi}_{OTP}^{W}-\overline{\pi}_{OTP}^{B}=(4+3\gamma^2-\gamma^3)\overline{a}^2/16(1+\gamma)(2-\gamma)^2>0$ always holds. For the non-deterministic profits, We have $V_{OTP}^{W-NN}-V_{OTP}^{B-N}=(1-\gamma)\rho^2\Delta^2\overline{a}^2/4(1+\gamma)>0$. Hence, $E[\pi_{OTP}^{W-NN}]-E[\pi_{OTP}^{B-N}]>0$ always holds. That is, $W-NN$ strategy always dominates $B-N$ strategy.

Next, we compare the OTP's expected profits under the agency introduction and the wholesale introduction strategies. For the deterministic profits, we can show that $\overline{\pi}_{OTP}^{A}-\overline{\pi}_{OTP}^{W}=H_9(\lambda,\gamma)\overline{a}^2/2(1+\gamma)(2-\gamma)^2(3\gamma^2+\lambda\gamma^2-8)^2$, where $H_9(\lambda,\gamma)=(33\gamma^4+8\gamma^3-24\gamma^2-12\gamma^5-10\gamma^6+4\gamma^7)\lambda^2+[128-168\gamma^2-32\gamma+52\gamma^4-16\gamma^5-2\gamma^6+48\gamma^3]\lambda-32-2\gamma^5-32\gamma+16\gamma^3+32\gamma^2-7\gamma^4$. The sign of $\overline{\pi}_{OTP}^{A}-\overline{\pi}_{OTP}^{W}$ depends on the sign of $H_9(\lambda,\eta)$. There exists a unique λ_{13} making $H_9(\lambda,\eta)=0$. We can easily verify that $\overline{\pi}_{OTP}^{A}<\overline{\pi}_{OTP}^{W}$ if $0<\lambda<\lambda_{13}$, and $\overline{\pi}_{OTP}^{A}>\overline{\pi}_{OTP}^{W}$ if $\lambda_{13}<\lambda<1$. For the non-deterministic profits, we can show that $(V_{OTP}^{A-NI}+F_{OTP}^{A})-(V_{OTP}^{W-NN}+F_{OTP}^{W})=\frac{((-2\gamma^2+\gamma^4)\lambda^2+(32+2\gamma^4-4\gamma^3-20\gamma^2)\lambda+14\gamma^2-4\gamma^3-3\gamma^4-32)\rho^2\Delta^2\overline{a}^2}{2(1+\gamma)(3\gamma^2+\lambda\gamma^2-8)^2}<0$always holds.

Based on the above results, we get that $\overline{\pi}_{OTP}^{W}>\overline{\pi}_{OTP}^{A}$ and $F_{OTP}^{W}+V_{OTP}^{W-NN}>F_{OTP}^{A}+V_{OTP}^{A-NI}$ in R11, so $W-NN$ strategy is optimal. Besides, in R12 and R13, we derive $\overline{\pi}_{OTP}^{W}<\overline{\pi}_{OTP}^{A}$ and $F_{OTP}^{W}+V_{OTP}^{W-NN}>F_{OTP}^{A}+V_{OTP}^{A-NI}$. Therefore, the OTP's optimal strategy also depends on $\rho\Delta$. We can easily get $\partial(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])/\partial(\rho\Delta)^2<0$. When $(\rho\Delta)^2=0$, we get $max(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])\rangle 0$. When $(\rho\Delta)^2=1$, there is a unique λ_{14} that satisfies $min(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])=0$. If $\lambda_{14}<\lambda<1$, then$min(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])\rangle 0$. Otherwise, $min(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])\langle 0$. As a result, when $\lambda_{14}<\lambda<1$ (i.e., in R13), we get $min(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])\rangle 0$, so the OTP prefers $A-NI$ strategy. When $\lambda_{13}<\lambda<min\{\lambda_{14},1\}$ (i.e., in R12), we derive that $max(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])\rangle 0$ and $min(E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}])\langle 0$. Obviously, in R12, there is a unique τ_5 that satisfies $E[\pi_{OTP}^{A-NI}]-E[\pi_{OTP}^{W-NN}]=0$. Hence, in R12, if $0<\rho\Delta<\tau_5$, then $A-NI$ strategy is optimal. Otherwise, $W-NN$ strategy is profitable.

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