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JOINT OPAQUE SELLING SYSTEMS FOR ONLINE TRAVEL AGENCIES

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1. INTRODUCTION

The emergence of the Internet has radically changed the tourism industry, the organization of tourism markets and the pricing mechanisms developed by tourism firms. Tourism is the best developed and most innovative online business,[1] supported by the emergence of various types of online travel agencies (OTAs) and sophisticated pricing and segmentation strategies. There are some leading global OTAs[2] that dominate the distribution

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1 Longhi [2004, 2009]; http://www.journaldunet.com/cc/10_tourisme/tourisme_marche_fr.shtml; http://www.journaldunet.com/ebusiness/commerce/e-commerce-en-france/sites-les-plus-rentables.shtml; http://webaly.co.in/ecommerce.html.

2 CheapOAir, Expedia, Opodo, Orbitz, Priceline.

of travel and tourism services; however, the spread of the Internet has allowed the emergence of niche players. Most of these smaller players specialise in specific market segments focused on particular destinations or services; some have experimented with innovative pricing models including opaque selling. Hotwire[3] and Priceline[4] are the two companies that have been the most successful in exploiting this latter strategy on the US market. They offer opaque products, that is, airline tickets and hotel rooms where the airline and travel schedule, the hotel name and exact location are only revealed when the payment is completed. Priceline has developed an online pricing mechanism which it calls Name-Your-Own-Price (NYOP), where, instead of posting a price, the seller receives offers from potential buyers which it can then accept or reject. Opaque models offer significant discounts to price conscious consumers with relatively low valuations of the product as the counterpart to opacity and uncertainty, and simultaneously allow suppliers to 'sell their excess inventory through a "brand-shielded model", thus enabling suppliers to maintain overall pricing integrity for their inventory'[5] and helping them to manage dynamically demand fluctuations for a fixed short-term supply.

According to TravelClick,[6] opaque selling OTAs accounted for 6% of the hotel reservations of major hotel brands in 2011. In addition, some 10,000 of 70,000 unsold airline tickets are sold daily through Priceline.com to leisure travellers, who account for over 90% of its customers. Priceline and Hotwire are ranked among the top 10 of most popular travel websites in the US, recording respectively 10.23% and 6.23% of overall US-based OTA's visits in March, 2012.[7] These evidences raise several questions. What are the advantages of such pricing systems for suppliers, intermediaries and consumers? Why would hotels and airline companies be willing to sell their products through Priceline/Hotwire and lose the advantage (and profit)

3 Acquired by Expedia in 2003.

4 Which has since acquired Booking.com in 2005, Agoda in 2007 and most recently Kayak in 2012, and since became one of leading market players. For more extensive information see Priceline.com Incorporated Company Pro le by *Marketline*, 2013.

5 http://www.traveldividends.com/programs/online-travel-agency-programs/

6 TravelClick Distribution Channel Performance Outlook Report, 1st Quater 2012, www.travelclick.com/infomation-center/bookings-by-channel.cfm

7 Data from Experian Hitwise, http://www.tnooz.com/article/priceline-narrows-gap-on-expedia-top-us-travel-sites-march-3-2012/

provided by product differentiation (Shapiro and Shi, 2008)? Why are firms willing to deviate from the standard practice of posting a take-it-or-leave-it offer? Do the firms find these strategies profitable?

The recent literature on opaque selling addresses these and similar questions. However, to our knowledge, there are no papers that compare the two strategies developed by Hotwire and Priceline and account for the opaque features of the products offered. The question we focus on is whether, since there are many variants of opaque selling systems, is there advantage to be gained from the simultaneous use of more than one distribution channel?

The remainder of the paper is organized as follows. Section 2 provides a review of the literature. It highlights the specific characteristics of opaque products and the advantages of opaque systems in tourism industry. It investigates the unique properties of the NYOP channel introduced by Priceline. Section 3 presents the analytical model. We are interested in the types of opaque selling systems that might be implemented by a given online monopoly to distribute airline tickets. We compare an opaque posted-price (PP) "Hotwire system" with a NYOP system with no possibility of rebidding, and the joint implementation of these two systems. We find that in a situation of imperfect (the travellers do not know the type and number of tickets that are available), but complete information (potential clients know their number and their respective propensity to pay), it is equivalent to implement the most efficient system (the NYOP system) or both systems in parallel. In section 4 we introduce the assumption of incomplete information (the travellers know their number, but not their relative propensity to pay). In this case, we find that, under moderate uncertainty, joint implementation of both booking systems dominates implementation of the NYOP channel only. The proofs are provided in the appendix.

2. OPAQUE SELLING: A LITERATURE REVIEW

We survey the literature on opaque selling, which focuses on either PP opaque selling or the NYOP channel. Opaque selling includes the PP models developed by Hotwire.com, Top Secret by LastMinute.com, and the

NYOP mechanism developed by Priceline.com. There are no studies that combine these two types of opaque booking mechanisms within the same intermediation structure.

With the exceptions of Wang *et al.* [2009], Shapiro, Zillante [2009] and Anderson, Wilson [2012], most work on NYOP selling mechanism ignores the question of product opacity. In this literature survey, we first present the contributions related to the opaque characteristics of the products and then focus on research on the NYOP booking channel.

2.1. Opaque Products

First, we analyse the characteristics of opaque products and the advantages of opaque selling. We focus on the contributions that consider what, in our opinion, is the most important feature of opaque selling, that is, that some key product's attributes or characteristics are concealed by the seller. This forces consumers to make their purchase decisions blind. From the service providers' point of view, we can identify two opposite effects. On one hand, by employing opaque selling the provider loses the advantages of product differentiation because, to consumers, opaque goods are indistinguishable and are perfect substitutes (Shapiro, Shi [2008], Jerath *et al.* [2010]). On the other hand, since it is not always beneficial to fully inform consumers about the market prices in case their price sensitivity increases and downward price pressures emerge, opaque selling enables service providers to generate incremental revenues without disrupting existing distribution channels or retail pricing structures (Smith *et al.* [2007], Shapiro, Shi [2008], Zouaoui, Rao [2009], Gal-Or [2011]). Opaqueness allows the service provider to distribute a distressed inventory at discounted prices through opaque intermediaries, which enable it to reach a different demand segment than can be achieved by traditional, transparent sales channels (Dolan, Moon [2000], Chen, Iyer [2002], Jiang [2007], Pizam [2011], Anderson, Wilson [2011]). Hence, it is beneficial for service providers to implement multichannel distribution using mechanisms that provide different levels of market transparency (Grandos *et al.* [2008], Anderson, Xie [2012]). In order to increase its revenues, the service provider might vary the price differential across different selling mechanisms and thus, successfully price discriminate clients (Fay [2008], Jiang [2007], Grandos *et al*. [2008], Shapiro, Shi [2008]), because consumer valuation of the product may be represented as a function of the channel's opacity (Anderson, Xie [2012]). In the case of competition between service providers, an issue that we do not tackle in the present paper, the introduction of an opaque channel increases the price competition for the low-value consumers' segment, but decreases it for the high-value consumers (Shapiro, Shi [2008]). This result is particularly important if high value consumers are sufficiently brand-loyal. On the other hand, if consumers' brand loyalty is rather low, the introduction of opaque selling may have the opposite effect (Fay [2008]).

Opaque selling can be regarded also as probabilistic selling, in which the opaque good is considered as a gamble involving a probability of getting any one of the sets of multiple distinct items (Fay, Xie [2008], [2010], [2012]). In this case, also, market segmentation is based on consumer uncertainty and heterogeneity in the uncertainty levels they can bear. In addition, since opaque intermediaries distribute the products of different service providers, opaque selling provides the seller with a buffer against its own uncertainty about the identity of the most popular product. Finally, the introduction of opaque selling is beneficial not only for the intermediary, it also affects overall welfare by enabling very price sensitive consumers to travel (Jiang [2007]).

2.2. Name-Your-Own-Price selling mechanism

NYOP is a popular method of selling excess inventory over the Internet. It was developed in 1998 by Priceline.com, which remains the largest NYOP seller worldwide. It is sometimes described in the literature as an auction (Spann, Tellis [2006], Bernhardt, Spann [2010], Anderson, Wilson [2011], Gal-Or [2011]) since NYOP and auctions have several similarities. When a consumer visits the website of Priceline (or some other NYOP intermediary), in presenting her query, she is asked to name the price she would like to pay for the product, and to complete all requested data (name, e-mail address, credit card number). Priceline then checks the prices of corresponding services, loaded into its database (GDS Worldspan) by the service providers. If it finds a product whose price is lower than the consumer's bid, the transaction takes place. Priceline keeps the difference between the listed price and the price paid by the client, which represents its margin (identified with another type of margin – informational – as the two sources of intermediary's profits by Hann and Terwiesch [2003] and Gal-Or [2011]). In the literature, it is usually assumed that the intermediary sets a threshold price above which it accepts the bids. If it does not find an appropriate product at a price corresponding to the consumer's bid, this bid is rejected. In the case of a declined bid, the consumer cannot reformulate the same query for 24h, but she can rebid immediately by changing at least one of the product's attributes (e.g. date, destination or departure airport in the case of bidding for an airline ticket, hotel location or star rating in the case of accommodation search). In this paper, we adopt this single-bid restriction in line with Wilson, Zhang [2008], Wang *et al.* [2009], Anderson, Xie [2012], Gal-Or [2011], Shapiro [2011]; however, the question of relaxing this restriction *i.e.* allowing multiple bidding remains an important issue in existing literature since perfect enforcement of the single-bid policy is not always possible (Fay [2004], Bernhardt, Spann [2010]). Fay [2004] shows that some consumers use illegitimate practices to bypass this restriction (e.g. a different credit card number and e-mail address), which is detrimental to the intermediary's profits. In practice, some NYOP sellers implement a multiple bidding policy and allow consumers to engage in online haggling (Hann, Terwiesch [2003], Terwiesch *et al.* [2005], Joo *et al.* [2012]), and progressively to raise their bids (Cai *et al.* [2009]) towards their reservation prices (Spann *et al.* [2004]) if their initial bids are rejected. Fay [2004] shows that, surprisingly, single-bid and multiple-bid policies do not modify the level of the intermediary's profits. Fay and Laran [2009] apply a joint policy of multiple-bidding and varying threshold price. They show that if consumers suppose the threshold price to be constant, their bidding pattern is monotonically increasing. However, if they expect it to vary, their bidding behaviour depends on their patience and the expected degree of threshold price variability. The fact of changing the threshold may attract and retain more customers, and does not necessarily reduce customer satisfaction (Fay, Laran [2009], Hinz *et al.* [2011]), which contrasts with what might be expected.

Another important feature of NYOP system, which is related to its profitability, is the secrecy surrounding the threshold price (Bajari, Hortaçsu [2003], [2004], Hinz, Spann [2010]). For bidders, it is important to learn the maximum on its level in order to bid near to it but not to overbid. In this paper we suppose that potential bidders estimate the thresholds levels,[8] perfectly in the case of complete information (*i.e.* the benchmark case) and imperfectly under uncertainty. In reality, in the context of the Internet, consumers share information on their successful and unsuccessful bids with their online communities and on forums (ex. BiddingForTravel.com, BetterBidding.com). Bidders use the available information in order to update their references prices, product valuations and beliefs about thresholds, in order to derive maximum savings (Joo *et al.* [2012]), all of which decreases the sellers' profits. NYOP intermediaries may react different to this information diffusion (Hinz, Spann [2010]). They may adapt their threshold prices levels (Fay, Laran [2009], Hinz *et al.* [2011]) or they may manipulate the quality and availability of the information diffused (Wolk, Spann [2008], Hinz, Spann [2010], Cai, Cude [2011], Spann *et al.* [2012]), by contributing to these forums or posting reference prices on their own websites. One possibility is to implement a Select-Your-Price mechanism (Spann *et al.* [2012]). In this case consumers are influenced by the range of possible candidate bids. Providing a list of possible bids could be perceived as a format that provides more information about the seller's threshold price and, thus, decreases the customer's uncertainty about the product's value. The effective bid amounts and intermediary's profits, depend on the level of possible bids provided. If they are too low or too high *i.e.* seem unrealistic or unacceptable, their effect will be negative.

In relation to the distribution of threshold prices, the most common customer belief, which we adopt in the paper, is that the threshold is uniformly distributed across an interval (Hann, Terwiesch [2003], Fay [2004], Terwiesch *et al.* [2005], Fay, Laran [2009], Wang *et al.* [2009]). In this paper, we adopt the assumption of uniformity of threshold distribution as a consequence of customers' uniform reservation price distribution. In our model consumers' valuations of tickets are uniformly distributed (on two identical segments). The literature includes similar settings (Fay [2004], Almadoss, Jain [2008], Wang *et al.* [2009], Anderson, Xie [2012], Shapiro [2011], Fay, Xie [2012]).

8 Following the assumption developed by Fay [2004], we consider that there are two possible thresholds: one when the supply is very limited, and the other when there are more tickets available. However, unlike Fay [2004], we assume the intermediary keeps both levels secret.

This paper compares the use of an opaque NYOP channel, an opaque PP channel, and their joint implementation. In the model, once the customer's bid is rejected, she cannot purchase the product via the opaque PP channel. This is the same assumption as in Wang *et al.* [2009]. The nonsequentiality of the booking mechanism is an important point, and it distinguishes our setting from the frameworks in the literature. In particular, Anderson and Xie [2012] consider a firm which tends to set optimal full information prices, opaque prices and an optimal threshold policy at the NYOP retailer. Although these prices are set simultaneously, sequential use of distribution channels is possible in this setting. Customers choose one of channels or, in the case of rejected bids, the sequence of channels. They make their decisions based on their valuation, PP levels, and on the probability of their bid being accepted. For the firm it is always optimal to post both full information and opaque prices, especially if the opaque price, as a function of the channel's opacity, converges to a full information price. However, in this framework, it is not always optimal to implement the NYOP channel. Shapiro [2011] compares a non-opaque NYOP and PP channels with risk adverse buyers. He shows that in the case of risk neutral buyers the NYOP profits coincide with the PP profits. If buyers are risk-averse, the NYOP profits outweigh the PP benefits. Then, like Anderson and Xie [2012], Shapiro considers a NYOP intermediary which adds to its offer a PP option. This option captures the demand of rejected bidders. Finally, Shapiro considers the same situation with the presence of a competitive alternative PP option. In this case, the seller needs to be cautious about modifying the PP in order not to lose its clients. This framework explains why Priceline has developed a PP non-opaque system on its website. The main differences with our paper and our contributions to knowledge, are that: first, we consider that the use of both models is simultaneous and following a rejected bid the customer has no possibility of acquiring the ticket; second, that the products are opaque; and third, that capacity is limited. In the opposite cases, the intermediary and potential clients would adopt different behaviour, therefore, the issue would not be the same (Cai *et al.* [2009], Fay, Xie [2012]).

3. DIVERSIFICATION OF OPAQUE CHANNELS WITH COMPLETE INFORMATION

Despite the extensive literature, there is one question that has not been addressed, that is, since many variants of opaque systems exist, is there an advantage in using simultaneously more than one distribution channel? This is the question addressed in this paper.

The answer is complex and depends on many circumstances, mainly the competitive environment. If we consider a competitive game, in which every competitor chooses one channel, the equilibrium could be asymmetric, where each intermediary specialises and distributes on a specific channel. If Agencies A, B and C compete on alternative channels: opaque PP, transparent Last Minute and opaque NYOP channel, each should specialise in different types of selling and should serve specific demand segments.

If there is only one agency in a monopoly position and the objective is to find the best allocation of potential travellers on alternative channels, the best solution, theoretically, would be first-degree price discrimination. As in many other cases, this strategy is not implementable due to its complexity, and because the consumers' willingness to pay is private information and there is no incentive for its revelation. The NYOP opaque solution (the Priceline system) seems to be the most similar. Suppose that the population of travellers is risk-neutral, fully informed about the characteristics of unsold tickets (airline, departure time, etc.) and knows perfectly the distribution of other potential travellers' propensities to pay, each consumer is able to bid (or not) a price corresponding to her reservation price, given the uncertainty about the number of seats available and their attributes. However, this result depends on the level of incompleteness of the potential traveller's information. Suppose for instance that potential travellers with a high propensity to pay are less well informed about the ticket distribution and the propensity to pay of other agents. In this case, they will likely over-estimate the utility they can derive from the NYOP channel and bid a lower price than they would under complete information. In this case, implementation of a last minute channel would be a better strategy. However, this solution has one main inconvenience: it has a negative effect on the existing pricing structure, by creating a downward pressure. In this paper we consider the last minute selling channel as complementary to the opaque channel.

It is complicated to decide whether two or more forms of opaque channels can coexist. Consider, for instance, the opaque NYOP Priceline and the opaque PP Hotwire channels. Both channels are opaque, *i.e.* do not give precise information to the would-be travellers about the quality of the travel. Again, if all passengers had complete information on flight frequency and other ticket attributes, and if they knew precisely the distribution of the other consumers' propensities to pay, all would choose to use only the NYOP system, and would quit the PP channel, which would be rendered redundant. In the following subsection we try to confirm this intuition.

3.1. The model

There are $2n$ potential travellers distributed in two sub-populations of n agents, both willing to travel from city 1 to city 2. The travellers belonging to the sub-population A prefer the 7:00 flight and the sub-population B – the 18:00 flight. Each subset of n potential travellers is distributed uniformly on a segment $[0,a]$ with $a>0$. The gross utility of traveller i, located at the point $a_i>0$ on the segment $[0,a]$ is $a_i(u+\bar{u})$, $\{u,\bar{u}>0\}$ when she travels at her preferred time and only $a_i u$ when she takes the other flight. All travellers are risk neutral, *i.e.* they care only about maximizing their utility. If a traveller decides not to purchase the product and not to bid, or her bid is not accepted, her utility vanishes. In the case of a rejected bid, the unsuccessful bidder has no possibility of rebidding or buying the ticket on the PP channel.

There is one OTA, which is in a monopoly position[9] and implements an adapted opaque selling system in order to distribute flight tickets from city 1 to city 2 for given airlines. It maximizes its and the airlines' profits. To keep the results simple, we consider that the OTA does not bear any costs; for any costs level, the analysis yields the same insights. We suppose that the OTA receives a fixed percentage of each ticket sold since it operates under a merchant model[10].

9 Priceline.com benefits from a monopoly position in the U.S. market due to its booking system Name-Your-Own-Price being patented.

10 It receives a commission after each booking, but makes no commitment on inventory, therefore it takes no risk.

Each day there are two flights from city 1 to city 2: the first leaves at 7:00 and the second at 18:00. The number and the nature of available seats are estimated with a small error just a few days before the flight departure date. There are five possible states of the world, defined in Table 1. The OTA knows their distribution and the potential travellers' number and locations on the two segments. There are always more potential travellers than available seats in all states of the world, *i.e.* $n \gg m$. Tickets are sold on a first-come-first-served basis.

Table 1. Available seats for the flights from city 1 to city 2 on a given date

States of the world	Number and type of available seats	Probability
1	m at 7:00	1/4
2	m at 18:00	1/4
3	$2m$ at 7:00	1/8
4	m at 7:00 m at 18:00	1/4
5	$2m$ at 18:00	1/8

The OTA implements either:

(i) an opaque PP system;

(ii) an opaque NYOP system;

(iii) both systems jointly.

The sequence of actions is as follows:

- At stage 1, the OTA chooses among (i), (ii) and (iii). If it selects (i) or (iii), then at the same moment it sets the price of the PP channel. If the OTA chooses (ii) or (iii), it launches a single bidding process for the tickets.
- At stage 2, if the OTA initially chose (i), potential travellers will decide to buy or not a ticket on the PP channel. If the OTA selected (ii), they will choose to post or not a single bid. If the OTA chose (iii), potential travellers will decide to buy a ticket on the PP channel, or to bid on the NYOP channel, or to reserve.
- At stage 3, the OTA knows the exact number and nature of the available seats on each flight. If (i) or (iii) was chosen at stage 1, the OTA

delivers the tickets to its clients on the PP channel. If (ii) or (iii) was selected, the agency fixes the threshold price for the NYOP channel and sells the tickets to those bidders whose bids exceeded this threshold. Each successful bidder pays the rate she posted.

The relevant equilibrium concept is a Stackelberg equilibrium, where the OTA is the leader. The game is solved by backward induction. At stage 3, the OTA chooses the best action (i.e. it fixes the threshold price of the NYOP channel if (ii) or (iii) was selected), given potential travellers' actions at stage 2. At stage 2 potential travellers choose their own best options, given the OTA's decisions at time 1 (the distribution system chosen and the PP channel rate, if strategies (i) or (iii) were implemented), OTA's expected decisions at stage 3, and the probability of their bids being accepted. At stage 1, the OTA chooses the appropriate distribution strategy and the rate applied on the posted-price channel if strategy (i) or (iii) is implemented.

We suppose that information is imperfect, but complete, *i.e.* travellers know the states of the world and their respective probability, but they do not know which is realized.

3.2. The optimal choices of the OTA

Let us consider the three OTA solutions in order.

(i) If the opaque PP channel is implemented on its own, the OTA at stage 1 sets the price p^{PP}, which maximizes the airlines' and OTA's joint profit $\pi(p^{PP}) = mp^{PP}$. The number of seats available for the channel is fixed at stage 1 as m, which is the highest number of seats always available at stage 3 in all states of the world.[11] Then, the level of p^{PP} is such that the OTA extracts the whole surplus of the last traveller choosing the PP channel. Whatever the rate for this channel fixed at stage 1, the potential travellers, whose net utility is greater than or equal to zero at this rate, will choose to buy a ticket via this channel at stage 2. Then, the best solution for the OTA is to charge a rate that clears the last potential PP channel

11 Theoretically, the OTA could sell more than m tickets, because in some states of the world there are $2m$ tickets available. However, as in case of overbooking it would be sued and it prefers to implement the safety strategy of selling only m tickets.

client's surplus. These travellers are located on each segment at points a_i^1, such as $(a-a_i^1)/a=m/2n$, i.e. at $a_i^1=a(2n-m)/2n$. The resulting value of p^{PP}, which wipes out the net utility of agents located at a_i^1, then is $a_i^1(u+\bar{u}/2)-p^{PP}=0$, since the states of the world and the distribution of agents on the segments $[0,a]$ are common knowledge. Then, we obtain $p^{PP}=a(2n-m)(u+\bar{u}/2)/2n$ and

$$\pi^{PP}=mp^{PP}=(2nm-m^2)a(u+\bar{u}/2)/2n. \tag{1}$$

(ii) If the opaque NYOP channel is the only channel implemented at stage 3 and in each state of the world, the OTA chooses the higher threshold value, such that travellers, whose bids are greater than or equal to this threshold, clear the market. Since the OTA determines this value after observing the state of the world, there are two possibilities. If only m tickets are available, the price p_H^N is high: it corresponds to the reservation price of the $(n-m)^{th}$ traveller if potential buyers are ranked according to their increasing propensity to pay. If the number of available tickets is $2m$, the price p_H^N is lower because it corresponds to the propensity to pay of the $(n-2m)^{th}$ traveller, who integrates uncertainty in her expected utility function. At stage 2, the bidders are able to take account, in their decisions, of the optimal choices of the OTA and, among other things, to consider the possibility of their bids being accepted. If they are able to understand the NYOP system correctly, they will be able to calculate the last successful bid in each state of the world and may post it if it is lower than or at least equal to their reservation price. In the case of imperfect, but complete information, there exist two possible bids: p_H^N, which guarantees the travel in all states of the world, and p_L^N, which makes the travel uncertain. Potential travellers bid only p_L^N or p_H^N: their net expected utility is then defined by $a_i(u+\bar{u}/2)-p_H^N$ if they decide to bid p_H^N, and $\left[a_i(u+\bar{u}/2)-p_L^N\right]/2$, if they decide to bid p_L^N. Elementary calculus allow us to deduce the threshold values a_i^{2*} and a_i^{2**} separating on each segment $[0,a]$ potential travellers choosing not to bid and potential travellers bidding p_L^N, potential travellers choosing to bid p_L^N and potential travellers who bid p_H^N respectively. These values are $a_i^{2*}=a(n-m)/n$ and $a_i^{2**}=a(2n-m)/2n$. Then we can deduce the equilibrium threshold prices $p_L^N=a(n-m)(u+\bar{u}/2)/n$ and $p_H^N=a(2n-m)(u+\bar{u}/2)/2n$, and the joint airlines' and OTA's profit $pi^N=mP_H^N+mP_L^N/2$ or

$$\pi^N=(2mp_H^N+mp_L^N)/2=(3nm-2m^2)a(u+\bar{u}/2)/2n. \tag{2}$$

(iii) If both channels are implemented jointly, the OTA allocates the first set of m seats to the PP channel, targeting customers with a higher propensity to pay. The second set of m seats is assigned to the NYOP channel, serving the travellers with lower propensity to pay. At stage 1, the OTA chooses the price of the PP channel and offers the travellers the possibility to bid on the NYOP channel. As in case (i), the price of the PP channel is $p^{PP} = a(2n-m)(u+\bar{u}/2)/2n$. The NYOP channel attracts the next m travellers and the threshold price is $p_L^N = a(n-m)(u+\bar{u}/2)/n$. The joint profit of the airlines and the OTA then is $\pi^{PP/N} = mp^{PP} + mp_L^N/2$ or:

$$\pi^{PP/N} = mp^{PP} + mp_L^N/2 = (3nm - 2m^2)a(u+\bar{u}/2)/2n. \qquad (3)$$

Consequently, we can hypothesize that:

Proposition 1. If potential low rate travellers are completely informed about the random number and distribution of available seats, and the other agents' propensities to pay, it is equivalent for the airlines and the OTA to implement a NYOP channel alone or to implement the PP and NYOP channels jointly.

Proof: Expressions (1), (2) and (3) represent the airlines' and OTA's joint profits at Stackelberg equilibriums associated respectively with the implementation of the PP or NYOP channels and both channels jointly. Comparison among (1), (2) and (3) proves that, whatever the values of the parameters $u, \bar{u}, a, n$, and m, $\pi^{O/N} = \pi^N > \pi^{PP}$, it is equivalent for the OTA to implement the NYOP or both systems jointly.

According to the previous intuition, the opaque PP channel is not an optimal solution for potential travellers if it is implemented on its own. The travellers with a higher propensity to pay are indifferent between this selling mechanism and its joint implementation with the opaque NYOP channel, while the travellers with a low propensity to pay prefer the other two distribution strategies. We observe also that it is equivalent for high propensity travellers to pay p^{PP} on the PP channel or to use the NYOP channel.

4. JOINT OPAQUE CHANNELS WITH INCOMPLETE INFORMATION

There is a first type of information incompleteness that is associated with travellers' uncertainty concerning the stochastic distribution of demand on traditional channels. The seasonal, daily and hourly evolution of traditional demand follows complex laws which are not easily understandable by travellers. The statistical distribution of demand variations during the period could involve information incompleteness or information asymmetries, on the one hand between the OTA and the travellers, and on the other hand among the travellers. However, it is advantageous for airlines to partly adapt their supply to these variations. Consequently, it is advantageous for airlines and the OTA to spread the appropriate statistics on the available seat distribution for each destination, during every time sub-period. Then, we can assume that this lack of information is not the main reason for travellers' uncertainty, and can focus on the second type of information incompleteness. Bidders generally lack relevant information on other consumers' propensities to pay. The important number of potential travellers makes it difficult for each bidder to perceive the propensities to pay distribution. This lack of information has dramatic consequences: under information completeness, our example provides only two bid prices when the NYOP or the PP system and the NYOP jointly are implemented. In this case, whatever the traveller's propensity to pay, it will never be interesting for her to bid a price different from p_L^N or p_H^N. In contrast, under incomplete information, travellers cannot perfectly estimate p_L^N or p_H^N. Then, it might be rational for them to bid different prices if the selling system is the NYOP mechanism.

4.1. The general setting

Let us consider the segment that accommodates all potential travellers preferring the 7:00 (resp. the 18:00) flight, and assume that travellers do not know their precise position on this segment. This uncertainty implies that their estimations of the other travellers distribution on the segment, and especially the distance $[a_i, a]$ between their own location and the location of the agent with the highest propensity to pay, are imprecise. Then, we suppose that the agent located on a_i estimates a as $\tilde{a}$:

$$\tilde{a} - a_i = q(a - a_i) + (1-q)a_i, q \in [0,1]. \tag{4}$$

When $q = 0$, there is full uncertainty on a's position and the traveller locates herself in the middle of the segment $[0, a]$. When $q = 1$, the information on her position is perfect, so she can perfectly estimate the threshold levels, as described in the previous section. When q is strictly comprised of between 0 and 1, the uncertainty about the agent's location is more or less moderate. We suppose that the OTA is aware of the agents' confusion about their relative propensities to pay. Thus, we can consider the three possible strategic choices among the implementations of alternative selling mechanisms.

(i) If only the PP channel is implemented with price p^{PP}, all the travellers have information on prices when taking their decision at time 2. Their behaviour is unchanged compared to the behaviour in Section 3. They buy tickets if $a_i^1(u + \bar{u}/2) - p^{PP} \geq 0$ and do not if $a_i^1(u + \bar{u}/2) - p^{PP} < 0$. The result is the same as in case of complete information, *i.e.*, $p^{PP} = a(2n - m)(u + \bar{u}/2)/2n$ and

$$\pi^{PP} = mp^{PP} = (2nm - m^2)a(u + \bar{u}/2)/2n. \tag{5}$$

(ii) If only the NYOP channel is implemented, at time 2 the bidders estimate the probability of their bid being successful. Given (4), they still compare $a_i(u + \bar{u}/2) - p_H^N$ (their estimated net utility if they choose to bid p_H^N and expect to travel, in all states of the world) and $\left[a_i(u + \bar{u}/2) - p_L^N\right]/2$ (their estimated net utility if they choose to bid higher than p_L^N, but lower than p_H^N, and accept the possibility of not travelling if there are only m tickets available) and 0 (their estimated net utility if they decide not to bid). In this case, they are bound in their individual estimations of a_i^{2*} and a_i^{2**} to evaluate p_L^N and p_H^N. Given (4), they calculate $a_i^{2p*} = (aq - 2a_iq + 2a_i)(n-m)/n$ and $a_i^{2p**} = (aq - 2a_iq + 2a_i)(2n-m)/2n$, and then deduce $p_{Li}^N = (aq - 2a_iq + 2a_i)(n-m)(u + \bar{u}/2)/n$ and $p_{Hi}^N = (aq - 2a_iq + 2a_i)(u + \bar{u}/2)(2n-m)/2n$ – the threshold prices (depending on their location a_i, when the total number of seats is respectively m and $2m$). The higher the propensity to pay of the traveller located in a_i, the greater high and low threshold prices for the NYOP channel she will expect. Potential travellers located at a_i on one of the segments $[0, a]$ consider themselves marginal agents between travellers choosing the reservation and agents bidding at a low rate if $a_i = a_i^{2p*} = (aq - 2a_i q + 2a_i)(n-m)/n$, *i.e.* $a_i^{2p*} = aq(n-m)/[2nq - 2mq - n + 2m]$. Similarly, agents located on the same segment at $a_i = a_i^{2p**} = (aq - 2a_i q + 2a_i)(2n-m)/2n$, *i.e.* $a_i^{2p**} = aq(2n-m)/(4nq - 2mq - 2n + 2m)$ consider themselves as limit agents between the low rate and high rate bidders. Note that these thresholds depend on q, *i.e.* on the level of travellers' uncertainty about their relative positions on $[0,a]$. Then, at stage 2, potential travellers bids depend, first, on their position on $[0,a]$ and, second, on the level of uncertainty. Note that given (4), $a_i^{2p**} \geq a_i^{2**}$. Then, at stage 3, there are three possible cases based on parameter values and uncertainty levels:

case 1: $a_i^{2*} < a_i^{2p*} < a_i^{2**} < a_i^{2p**}$,
case 2: $a_i^{2*} < a_i^{2**} < a_i^{2p*} < a_i^{2p**}$,
case 3: $a_i^{2p*} < a_i^{2*} < a_i^{2**} < a_i^{2p**}$.

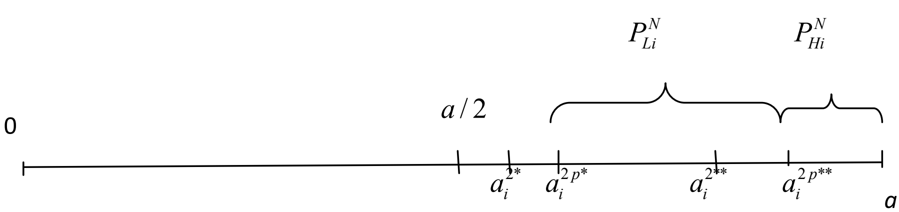
(iii) If the NYOP system is implemented jointly with the PP channel, the OTA still allocates the first set of m seats to the PP, targeting customers with a higher propensity to pay. The price of the PP channel p^{PP} is unchanged. The second set of m seats is still assigned to the NYOP channel and distributed to potential travellers with a lower propensity to pay. At time 2 the bidders estimate the probability of their bids being successful. Given (4), they still compare $\left[a_i(u + \bar{u}/2) - p_L^N\right]/2$ (their estimated net utility if they choose to bid higher than p_L^N) and 0 (their estimated net utility if they decide not to bid). In this case, they use their individual estimations of a_i^{2*} to evaluate p_L^N. Similar to the NYOP only strategy, they calculate $a_i^{2p*} = (aq - 2a_i q + 2a_i)(n-m)/n$, and then deduce the threshold price $p_{Li}^N = (aq - 2a_i q + 2a_i)(n-m)(u + \bar{u}/2)/n$. Again, the potential travellers located at a_i on one of the segments $[0,a]$ consider themselves marginal agents between travellers choosing reservation and travellers bidding at a low rate if $a_i = a_i^{2p*} = (aq - 2a_i q + 2a_i)(n-m)/n$, *i.e.* $a_i^{2p*} = aq(n-m)/[2nq - 2mq - n + 2m]$. Note that the threshold depends on q, *i.e.* the level of travellers' uncertainty about their relative positions on $[0,a]$. Then at stage 2, potential travellers' bids depend, first, on their position on $[0,a]$ and, second, on the level of uncertainty. Finally, under the joint implementation strategy, at stage 3 the three cases defined in (ii) still hold.

The first case is the most representative of the reality and, thus, is the case we analyse below. We dismiss the second case because according to the huge amount of easily available information, including information on external reference prices,[12] it is unrealistic to consider high levels of consumer uncertainty. We dismiss the third case because it implies a large number of tickets $m > n/2$ (compared with the number of potential travellers), which means that, in the absence of an additional clearance channel (opaque PP or opaque NYOP or even classic last-minute), airlines would experience a huge excess capacity. Although during the crisis period, the trend among most airlines has been to reduce capacity to an optimum level in order to minimize excess capacity, consequently we consider this third case to be unrealistic.

4.2. Average number of tickets, moderate uncertainty

In the first case we suppose that the number of available tickets is less than half the number of potential travellers, $m < n/2$. In this case all served travellers are located on the segment between $a/2$ and a, *i.e.* $a_i^{2p*} > a_i^{2*} > a/2$.[13] By moderate uncertainty we mean that $q \in [1/2, 1]$, which implies that a_i^{2p*} is lower than a_i^{2**}.

Figure 1. Case 1, $2m$ tickets available



In this case, when the NYOP system is implemented, as illustrated in Figure (1), the threshold between the bids of those who expect to travel

12 For an extensive analysis of this issue see Chernev [2003], Kamins *et al*. [2004], and Wolk, Spann [2008].

13 Remained that a potential traveller is someone interested in travelling at a positive utility rate: it is realistic to suppose that there are always potential travellers, especially during holiday periods, which are willing to purchase tickets, if their price decreases sufficiently.

in all states of the world and those who expect to travel only if a large number of tickets is available, is higher than in the case of complete information. Consequently, travellers under-estimate the number of travellers able to travel in all states of the world. Therefore, bidders located between a_i^{2p**} and a pay higher (and different) rates than in the case of complete information (and they are sure of travelling in all states of the world), while the travellers located between a_i^{2**} and a_i^{2p**} pay lower (and also different) rates (and suffer the same level of uncertainty of their bid being accepted as in the case of complete information). At the same time, the travellers located between a_i^{2p*} and a_i^{2**} pay relatively high[14] (and different) rates and travel only if $2m$ tickets are available. Finally, potential travellers located between a_i^{2*} and a_i^{2p*} do not bid because, under the prevailing uncertainty, they believe that the lower threshold price P_{Li}^N corresponds to the relative propensity to pay of the agent located at a_i^{2p*} and, consequently, that their bid would not be sufficiently high. When the number of available tickets is $2m$, the result again is an extra-profit for the OTA and the airlines, derived from selling tickets to the subset of travellers located between a_i^{2p*} and a_i^{2**}, and the remaining unsold tickets corresponding to potential travellers located between a_i^{2*} and a_i^{2p*}.

When the PP channel is implemented on its own, only the travellers located between a_i^{2**} and a choose to travel at the uniform posted rate corresponding to a_i^{2**} on the segment.

When the PP and NYOP systems are implemented jointly, the travellers located between a_i^{2**} and a still choose the PP system, while the travellers located between a_i^{2p*} and a_i^{2**} still choose to bid relatively high[15] (and different) prices and travel only if $2m$ tickets are available. Then, the PP channel remains dominated by the joint implementation of the two systems. The relevant comparison is between only implementation of the NYOP channel, and its joint implementation with the PP system and, especially, from the OTA's point of view, the profits generated by the travellers located between a_i^{2**} and a in case of NYOP and joint implementation.

14 As compared to a_i^{2*}, the threshold level in situation of complete information.

15 Compared to a_i^{2*}.

If the NYOP channel is implemented alone, the OTA profits are expressed by (6)

$$\pi^N = 1/2 \times \pi^N(m) + 1/2 \times \pi^N(2m), \tag{6}$$

with

$$\pi^N(m) = 2\sum_{k=1}^{m_H^D/2} P_{Hi}^N \left[a_i^{2p**} + (k-1)(a - a_i^{2p**}) / [(m_H^D/2) - 1] \right] +$$
$$+ 2 \sum_{k=1}^{(m-m_H^D)/2} P_{Li}^N \left[a_i^{2**} + (k-1)(a_i^{2p**} - a_i^{2**}) / [((m - m_H^D)/2) - 1] \right],$$

and

$$\pi^N(2m) = 2 \times \sum_{k=1}^{m_H^D/2} P_{Hi}^N \left[a_i^{2p**} + (k-1)(a - a_i^{2p**}) / (m_H^D/2) - 1 \right]$$
$$+ 2\sum_{k=1}^{m_L^D/2} P_{Li}^N \left[a_i^{2p*} + (k-1)((a_i^{2p**} - a_i^{2p*})) / (m_L^D/2) - 1 \right],$$

where $m_H^D = 2n\dfrac{(a - a_i^{2p**})}{a}$ and $m_L^D = 2n(\dfrac{a_i^{2p**} - a_i^{2p*}}{a})$, given the level of uncertainty corresponding to case (1), represent the number of tickets obtained by travellers bidding high and getting a ticket in all states of the world, and the number of tickets obtained by travellers, who bid low for a ticket if $2m$ tickets are available.

If the OTA decides to implement both systems jointly, its profits are given by equation (7):

$$\pi^{PP/N} = (2nm - m^2)a(u + \bar{u}/2)/2n \tag{7}$$
$$+ \sum_{k=1}^{(m_L^D/2 + m_H^D/2 - m/2)} P_{Li}^N \left[a_i^{2p*} + (k-1)(a_i^{2**} - a_i^{2p*}) / ((m_L^D/2 + m_H^D/2 - m/2) - 1) \right]$$

Let us begin with an illustration of joint implementation of the PP and NYOP systems strongly dominating implementation of only the NYOP or only the PP channels. We choose the case where $n = 9$ and $m = 4$. In this case, each subset of n agents is located on the segment $[0, a]$.

In the case of complete information, travellers 8 and 9 are able to fly in all states of the world and travellers 6 and 7 are able to travel only when there are 8 tickets available (recall that there are $2n$ travellers located on two segments). We normalize $a=1$ and settle the threshold values $a_i^{2*}=11/18$ and $a_i^{2**}=15/18$, which correspond respectively to the reservation prices of the 6^{th} and 8^{th} travellers.

Then, we consider the case of incomplete information. We choose $q=35/36$, which corresponds to a very moderate level of uncertainty (with $q=1$, the potential travellers have complete information on other bidders' reservation prices). Since in this case a_i^{2p**} is located between a_i^{2**} and a, when only the NYOP system is implemented, only the traveller 9 chooses to bid high (which makes her flight certain), while travellers 7 and 8 choose to bid low (with the probability $p=1/2$ to travel), and agent 6 does not bid. When there are $m=4$ tickets available, only agents 8 and 9 travel and (in this case) at very different rates. Given the parameter values, we obtain $a_i^{2p**}=a_9^{2p**}$, which can be deduced from the general formula $a_i^{2p**}=(aq-2a_iq+2a_i)(2n-(m-1))/2n$, which, when m and n are small, overtakes the approximation $a_i^{2p**}=(aq-2a_iq+2a_i)(2n-m)/2n$. The first traveller's bid corresponds to $a_9^{2p**}=0.859$, while the second traveller's bid: $a_8^{2p*}=0.613$. The sum of their bids 1.472, is the OTA's profit obtained by distribution to the high rate population when only the NYOP system is implemented. When both systems are implemented jointly, agents 8 and 9 choose the PP system and each pays the PP, which corresponds to the reservation price of agent 8: $a_8^{2**}=0.833$. The resulting profit for the OTA is 1.666, compared to the profit obtained when the NYOP system is implemented on its own, of 1.472. Since agent 7 still bids the same amount a_6^{2p*} with or without the PP system and agent 6 still does not bid, joint implementation of these two systems provides higher profits to the OTA.

We generalize this observation in the following proposition:

Proposition 2. When n, m and q are such that $a_i^{2*}<a_i^{2p*}<a_i^{2**}<a_i^{2p**}$, joint implementation of the PP and NYOP is always the best solution for the OTA.

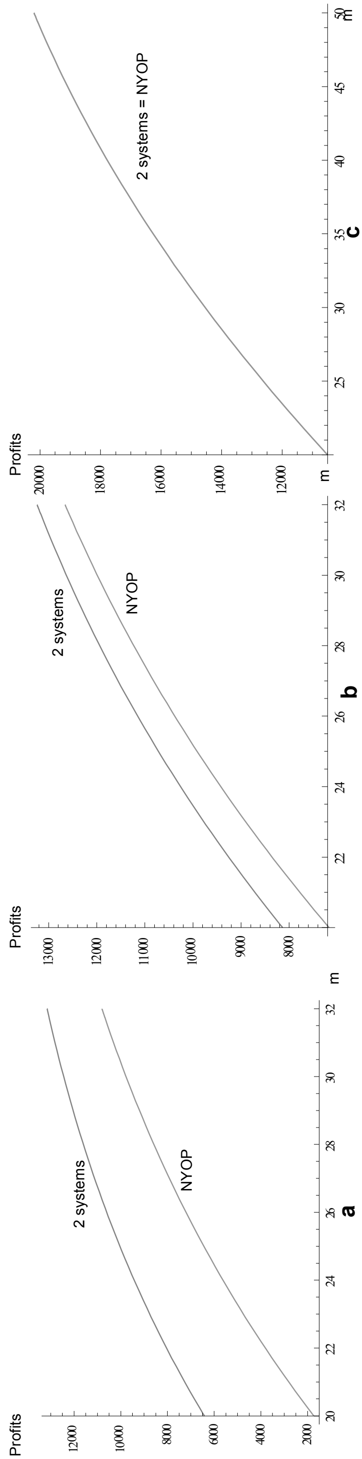
Proof: see Appendix 1.

When we compare joint implementation of these systems with implementation only of the NYOP channel, consumers located between a_i^{2*} and

a_i^{2**} choose the same options. Therefore, we focus on travellers located between a_i^{2**} and a. In the case of joint implementation, all these consumers travel and pay the same opaque PP of P^{PP}. If only the NYOP system is implemented, the same agents pay very different prices. Consumers located between a_i^{2p**} and a are sure of being able to travel in all states of the world by bidding high prices, evaluated individually, P_{Hi}^N. These bids are higher than the opaque PP would have been. Alternatively, consumers located between a_i^{2**} and a_i^{2p**} are convinced that the threshold price, which guarantees travel in all states of the world, is higher than their reservation price and, thus, bid much lower prices, evaluated individually, P_{Li}^N, which enable them to travel only if there are $2m$ tickets available. Their estimation of their position on the segment is much lower than the reality. Whatever the number of available tickets, they will be able to travel. The bids P_{Li}^N are lower than the opaque PP P^{PP} would have been. These bids converge to the reservation price of the agent who considers she would be the last to travel, if there were $2m$ tickets available, *i.e.* a_i^{2p*}. The profit surplus resulting from high bids does not compensate the profit loss from low consumer bids.

The spread between the two profits as a function of the number of tickets available $m \in [20,32]$, increases with the uncertainty, as illustrated in Figure 2a,b,c. Figure 2a illustrates the case of relative uncertainty, $q = 0.7$; Figure 2b illustrates moderate uncertainty, $q = 0.8$, and finally Figure 2c illustrates the case of no uncertainty, $q = 1$, when both profits are equal. All other parameters remain unchanged and are normalized to: $a = 20$, $u = 15$, $\bar{u} = 10$ and $n = 75$.

Figure 2. Comparison between NYOP and joint implementation in case 1



5. CONCLUSION

Drawing on the literature reviewed, which illustrates the extent of the questions raised by opaque selling in tourism, this paper considered the possibility of joint implementation of two different opaque systems by the same OTA. The first is the PP channel; the second takes the form of an auction where only travellers bidding over the unknown (hidden) threshold prices are sure to travel in all states of the world.

We built a three-stage game model describing the optimal choices of a travel agent facing the population of potential travellers with differentiated reservation prices. We studied this game in the context of potential travellers' imperfect, but complete information. In this case, potential travellers do not know the exact number and characteristics of available seats, but they do know the states of the world and their corresponding probabilities. They also know the number of potential travellers and their respective reservation prices. These assumptions are usual in the first strand of developments of an opaque pricing strategy analysis. With these types of assumptions, and assuming risk neutrality to analyse the travellers bids in the NYOP case, we find that joint implementation of the NYOP and PP systems provides no advantages over single implementation of the NYOP channel. Obviously, since, all things being equal, risk adverse travellers tend to prefer the PP system to the more risky NYOP auction, risk aversion might be a reason for implementing the PP system as an alternative to NYOP. Since travellers' risk aversion of travellers is not easily observable and probably less important for the low valuation traveller subpopulation, the choice of only the NYOP system is the best solution since, joint implementation of the two systems would increase operational costs and probably complicate the traveller's choice for no good reason.

We next extended the model to the case of incomplete information. In this case, the individual traveller does not know the characteristics of any other traveller. We limit this unawareness to reservation price levels and suppose that the number of potential travellers is known. This case has never been considered explicitly in the literature despite its relevance for real-life contexts, where the number and other statistical characteristics of given potential travellers are difficult for other bidders to identify. Several cases can be considered, related to the proportions of potential travellers and available tickets in each state of the world. We focus on the case we consider the most relevant: average number of available tickets relative to the number of potential travellers, and moderate uncertainty related to the distribution of other agent characteristics. We find that in this setting joint implementation of the PP and NYOP systems always dominates single implementation of the NYOP channel, even with the risk neutrality hypothesis we assume in this study.

A first basic extension would be to consider the other two cases. For instance, the context of strong uncertainty and the PP system on its own dominating, could have interesting properties. More interesting, would be to consider competition among OTAs in a market with a small number of intermediaries. Would a 'separating' solution be the best in this case, with the opaque PP system chosen by one OTA and the opaque NYOP by another, or would these competing agents reap advantage from each implementing both systems?

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Appendix 1: Proof of Proposition 2

Given that potential travellers located between a_i^{2*} and a_i^{2**} choose the same action whether the NYOP is implemented alone or jointly with the PP system, we consider only the optimal actions of potential travellers located between a_i^{2**} and a . According to the relative values of n , m and q , every agent j belonging to this subset chooses to bid prices P_{Hj}^N or P_{Lj}^N , according to her own position related to a_i^{2p**} . If the agent is located between a_i^{2**} and a_i^{2p**} , she chooses to bid a low price P_{Lj}^N . If she is located between a_i^{2p**} and a , she bids the high price P_{Hj}^N . If the two systems are implemented jointly, all potential travellers located between a_i^{2**} and a pay p^{PP} . Equations (6) and (7) can be expressed by (8) and (9) respectively:

$$\begin{aligned}\pi^N = {} & 1/(8n^2(n+m(-1+q)-2nq)^2)a(n^3(m(-2+q)-2n(-1+q))q \\ & +2(m-n)^2(-1+q)(m+n(-2+q)-mq)(n+m(-1+q)-2nq)) \\ & +n^3q((m-2n)(m(-2+q)-2n(-1+q)) \\ & +(2m(m-n)nq(n+m(-1+q)-2nq))/(n+2m(-1+q)-2nq)^2))(2u+\bar{u}),\end{aligned} \tag{8}$$

and

$$\begin{aligned}\pi^{O/N} = {} & 1/4a(m(2-m/n)-((m-n)(mn(5-4q)+2m^2(-1+q)+2n^2(-1+q))q) \\ & /(n+2m(-1+q)-2nq)^2)(2u+\bar{u}).\end{aligned} \tag{9}$$

Comparison of the profit equations (8) and (9) shows that it is always more profitable for the OTA to implement both systems jointly than to implement only the NYOP channel. Indeed, there are no possible parameter values that make the profit π^N greater than the profit $\pi^{PP/N}$. In this comparison, we focus on profits driven by consumers located between a_i^{2**} and a . Indeed, it is more profitable for the OTA to provide these travellers with the opaque PP product rather than letting them bid at different price levels.[16]

16 Computation details are available upon request.

Figure 3. Comparison between NYOP and joint implementation in case 1 according to uncertainty level

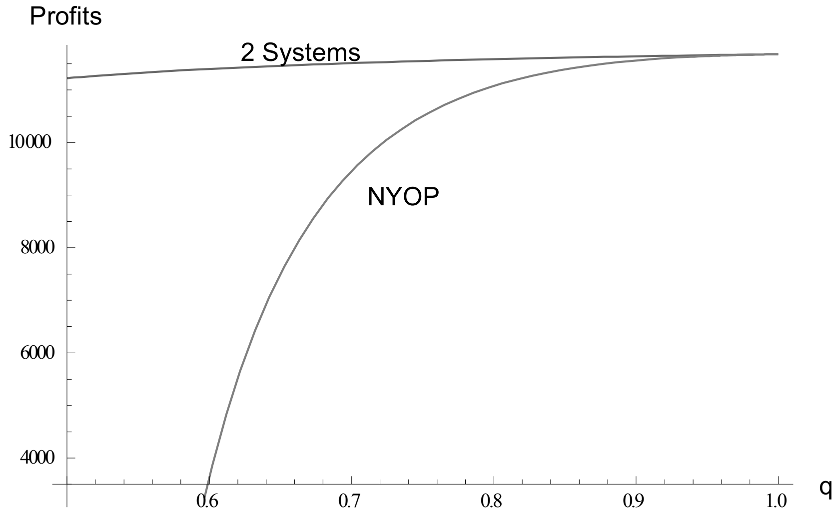

Figure 3 (3) illustrates that a decrease in the uncertainty level (corresponding to an increase in q from 0.5 to 1) reduces the spread between $\pi^{O/N}$ and π^{N}. These two profits become equal in the case of no uncertainty *i.e.* $q=1$. All other parameter levels are normalized to: $m \leq n/2$ with $m=32$ and $n=75$, $a=20$, $u=15$ and $\bar{u}=5$.

According to Figures (2) and (3) the conditions on parameters a, u, $\bar{u}$, $1/2<q<1$ and the condition $m \leq n/2$ are sufficient to make π^{N} smaller than $\pi^{O/N}$ in all cases.