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Optimal pricing strategy based on market segmentation for service products using online reservation systems: An application to hotel rooms

Xiaolong Guo[a], Liuyi Ling[a], Chenchen Yang[a,*], Zhaoqiong Li[b], Liang Liang[a]

[a] School of Management, University of Science and Technology of China, 96 Jinzhai Road, Hefei, Anhui 230026, PR China
[b] Department of Finance, School of Economics and Management, Changsha University of Science & Technology, 960, 2nd Section, Wanjiali South Rood, Changsha 410004, PR China

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ABSTRACT

As an effective policy which brings the service providers high occupancy rate and generates more profit than fixed pricing, the dynamic pricing strategy is extensively used in the online distribution channel. This paper studies the optimal dynamic pricing strategy based on market segmentation for service products in the online distribution channel taking hotel rooms as an example. Firstly, the pricing model is built to maximize the hotel profit through a dynamic process. Then the solution methodologies based on Chebyshev's Sum Inequality and dynamic programming are provided for the linear demand case and non-linear demand case, respectively. The optimal number of segments and optimal boundaries can be obtained. The results suggest that an appropriate policy of market segmentation in using of online reservation systems is benefit for the service suppliers as well as the consumers. Finally, an illustration based on a 300-room hotel is provided for the more realistic non-linear case.

1. Introduction

In the service industries, numerous service providers are confronted with the dilemma that only a small fraction of products are sold on a given time and given capacity, while the unsold part cannot be kept in inventory for future use when the market demand surpasses the available capacity (Stolarz, 1994). For instance, in the hotel industry, the unbooked rooms in the low demand season cannot be inventoried to the high demand season for sale. As further evidence, the unsold seats of a plane cannot be retained to a future fight. Furthermore, the marginal profit of each sold product (such as a hotel room and an airplane ticket) is very considerable, while the unit variable cost is much lower than the high fixed cost (Ladany, 1996). Therefore, how to achieve the full utilization of the high margin and zero-salvage product capacity becomes a significant issue for the service providers.

Fortunately, the profits can be increased considerably with a proper pricing strategy provided by *Market Segmentation* (Ladany, 1996), which is "one of the most important strategic concepts contributed by the marketing discipline to business firms and other types of organizations" (Myers, 1996). For example, in the e-tourism era, the online reservation system (ORS) is widely used in the marketing of hospitality industries and makes it possible for e-consumers to reserve hotel rooms at anywhere and anytime with access to the Internet. Consequently, different segments for hotel rooms can be achieved by ORS with a dynamic pricing strategy respecting to the lead time of the reservations.

Furthermore, there are many hotels that adopt this kind of dynamic pricing strategies for their consumers. Abrate et al. (2012) collect the dynamic pricing data "*from almost 1000 hotels in eight European capital cities*", which implies that there are so many hotels using dynamic pricing strategy in their revenue management. For instance in practice (all the examples are selected and verified July 2012), Marriott International, Inc. (https://www.marriott.com) offers a 25–50% discount to the consumers who book rooms 30 days earlier through the Internet. Similar concession occurs at Hilton Hotels (http://www.hilton.com). Compared with a float discount strategy above, Hotel ICON (http://www.hotel-icon.com/), which established by School of Hotel and Tourism Management Hong Kong Polytechnic University, will provide a 20% fixed discount to her consumers who book rooms at least 14 days before their arrival date. All these successful dynamic pricing strategies are operating on the hotels' websites through their online reservation systems.

The dynamic pricing strategy segments the market of service products into different parts by the length of the lead time to the end of the horizon. Take hotel rooms as an example, a higher rate

* Corresponding author. Tel.: +86 551 63603461.
E-mail addresses: gxl@mail.ustc.edu.cn (X. Guo), lyling@ustc.edu.cn (L. Ling), yangcc@mail.ustc.edu.cn (C. Yang), zqli@mail.ustc.edu.cn (Z. Li), lliang@ustc.edu.cn (L. Liang).

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for business travelers who reserve room on the target day or one or two days earlier; a medium rate for tourists who reserve rooms a longer time before the target day, like a week; and a lower rate for consumers who book rooms more than two weeks earlier before the target day. Due to the price concession, the pricing policy attracts more consumers for the service providers and most products are sold in advance of the end of the horizon. However, once all of the service products are booked before a long time of the horizon finished, the consumers who want to purchase the service near the target day will be declined due to the finite capacity. This may incur an opportunity loss of the profits to the service providers, because the margin is higher if the purchasing time is closer to the end of the horizon.

Consequently, how to determine the optimal dynamic pricing strategy, i.e., the optimal segmentations and the corresponding sale prices are the key issues in revenue management of the service providers in using of online reservation systems in the e-commerce era. Taking the hotel industry as an example, in this paper, we build a pricing model to describe the dynamic pricing process for the service providers. The efficient solution methodologies are outlined for both the linear demand function case and the non-linear case. Finally, the optimal solution of segmentations and the corresponding number of hotel rooms and price in the non-linear case are given by a numerical example with a 300-room hotel.

To the best of our knowledge, this paper may be the first attempt to determine the optimal dynamic pricing strategy in using of ORS in service industries. The remainder of this paper is organized as follows. After reviewing the related literature about dynamic pricing and market segmentation in service industries in Section 2, Section 3 presents the dynamic programming model of the pricing strategy based on market segmentation. In Section 4, we provide the solution methodology for the pricing model. A numerical example for a 300-room hotel is presented in Section 5. And finally, in Section 6 we discuss the management insights of our model and provide some research directions for further study in this field.

2. Literature review

Two distinct streams of related literature should be considered, pricing strategy in service industries (especially the tourism and hospitality industry) and market segmentation.

2.1. Dynamic pricing strategy

Pricing strategy is a critical topic among academic research. As the pioneer theoretical contribution in the hospitality industry, Gu (1997) suggests that the hotels should use a quadratic room pricing model rather than the $1 per $1000 approach and the Hubbart Formula, which are the two traditional well-known cost approaches. Along with his work, more and more researchers work on the pricing problem about hotel rooms. For instance, Lai and Ng (2005) study the optimal pricing model in the circumstances of uncertainty. Pan (2007) analyzes the influence of market demand and hotel capacity on the optimal pricing strategy. As an efficient marketing policy, van der Rest and Harris (2008) prove that discount is the best pricing policy for hotels in some cases like the demand has rigid changes. Ling et al. (2012) propose an optimal pricing model for the hotels with long-term stay service. Guo and He (2012) study the pricing decisions when hotel room plays as a part of travel package.

In the cooperation relationship with other organizations, the online pricing issue about hotel rooms has been paid enough attentions in recent years. Ling et al. (2011) provide an optimal pricing strategy for small or medium sized hotels in the cooperation with third-party websites or online travel agencies based on a Stackelberg game model. Afterwards, Guo et al. (2013) study the cooperation contract between hotels and third party website from the pricing perspective through a network consists of multi hotels and single website. All the above studies identify that pricing is one of the most important strategy of hotel management.

Hotels face the problem that rooms have high fixed cost and low variable cost, and what's more, the unsold rooms remain zero salvage value. Therefore, in order to gain maximal revenue, hotels have strong incentive to sell all the rooms out by the target day. As a pioneer work on dynamic pricing, Gallego and van Ryzin (1994) provide an optimal dynamic pricing model for the problem of selling a given stock of items by a deadline. They formulate this problem using intensity control and obtain structural monotonicity results for the optimal price as a function of the stock level and length of the horizon, and finally, they give useful insights to the retailers selling fashion and seasonal goods as well as the managers of the travel and leisure industry, especially the hotels and airlines. Burger and Fuchs (2005) also point out that dynamic pricing would be a future business model of airlines, which has the same product feature with hotels. Following Gallego and van Ryzin's work, numerous papers about dynamic pricing under different scenarios were published, for instance, multiple products (Bertsimas and de Boer, 2005; Gallego and Ryzin, 1997), multi-generation products (Kuo and Huang, 2012), stochastic demand (Zhao and Zheng, 2000), inventory control (Adida and Perakis, 2010; Bertsimas and de Boer, 2005; Chen and Simchi-Levi, 2004), revenue management (Gallego and Ryzin, 1997; MacDonald and Rasmussen, 2010; Tsai and Hung, 2009), and even strategic consumers (Bansal and Maglaras, 2009; Dasu and Tong, 2010; Kuo et al., 2011; Levin et al., 2009, 2010; Levina et al., 2009; Nasiry and Popescu, 2011). In their models, the price is formulated as a function of the inventory level and length of the horizon, that is to say, the optimal price will be changed every minute or even every second. However, in practice of the online reservation systems of hotels, we notice that the room price for a target day is not changed every day; it often keeps stable for some days. This is a result of two factors which are overlooked in the models of the above literatures, (1) the demand rate of hotel rooms is different along with the time closing to the target date, and (2) hotels must undertake an operational cost of the dynamic pricing policy. And in practice, these two factors are important elements which influence the pricing decisions in many industries, especially the service industries. In order to fill this gap, we introduce a new dynamic pricing model considering the operational cost and dynamic demand for service products sold on the Internet through online reservation systems.

2.2. B2C E-commerce and market segmentation

As an efficient policy, market segmentation is adopted widely in the pricing (and revenue) management both in practice and in academic research. Thus, there are more and more researchers work on this issue, in particular with the rapid development of the business-to-consumer e-commerce. Yelkur and DaCosta (2001) study the differential pricing for hotel services sold on the Internet, and find that hotels are able to take advantage of differential pricing for various segments, thanks for the fact of that the market for hotels can be divided into narrow consumer segments. Taking airline as an example, Toh and Raven (2003) outline the essentials of perishable asset revenue management, and find that market segmentation based on price discrimination is a good choice for the managers of perishable products. Guo et al. (2009) prove this viewpoint through providing a mathematical model of market segmentation application in the airline industry, they build a dynamic model for the electronic airplane ticket through sorting them into multi-class according to different demands of passengers in different seasons.

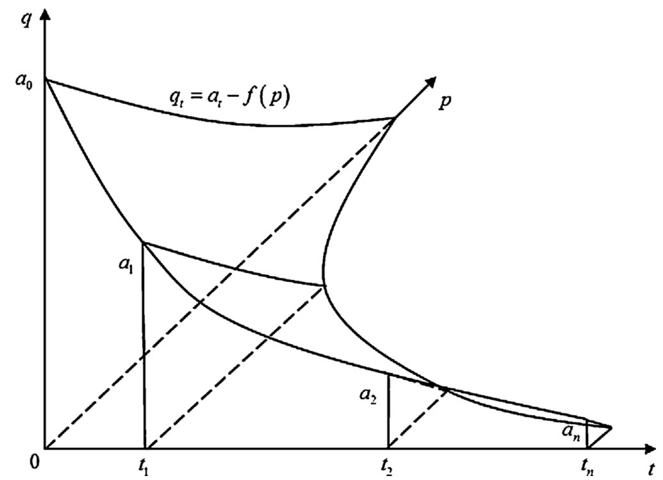


Fig. 1. Example demand curves.

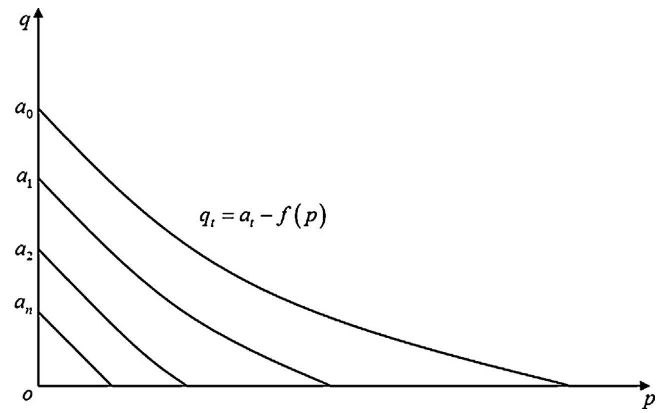


Fig. 2. The projections of the demand curves in *poq* coordinate system.

In addition, the market segmentation based on price discrimination can be realized by different characters of the consumers, like expenditure-based market (Legoherel, 1998), activities-based segmentation (McKercher et al., 2002), benefit-based approach (Tan and Lo, 2008) and culture (Najmi et al., 2010). Besides the single element approaches, Liu et al. (2010) develop a new mathematical model based on multi-objective evolutionary solution methodology according to the multi-criterion market segmentation. However, to our best knowledge, there is no literature about market segmentation based on the reservation lead time, and our paper is the first trying to obtain the optimal pricing policy based on segmentation respect to the reservation lead time through the application of online reservation systems.

3. Model description

We discuss the optimal pricing strategy of the service providers through the example of a hotel in this paper. The model supposes that all the consumers book rooms through the ORS of the hotels, for the reason that different ways of the tourists booking hotel rooms can be considered independent from each other in practice. For example, the consumers joined into a tour will get rooms through the travel agency by group booking; the commercial travelers often book rooms by phone or in person, scarcely ever through the ORS; and in general, the ORS consumers are usually individual travelers instead of travel agencies or any third-party organization. Hence, the consumers who book rooms through other ways but the ORS can be ignored without any effect of our model.

A hotel with a capacity of C identical rooms opens her online reservation systems to the consumers with dynamic pricing respect to the lead time of the reservations made. We assume that at time t before the target day, the demand curve shows the number of rooms demanded, q_t, is given by the decreasing relationship of the room rate, p, that is $q_t = a_t - f(p)$, where $a_t = g(a_0,t)$ is the sale saturate market demand of hotel rooms, increasing with the time closing to the target day; and $f(p)$ is an increasing function of p, respect to the consumer sensitivity (as an example shown in Fig. 1).

The expected sale saturate market demand of a hotel may change among different demand seasons influenced by various factors like weathers, tourists' nationalities, global events and even cultures (Fernández-Morales and Mayorga-Toledano, 2008; Pan, 2007). Hence, there may be different optimal decisions for different demand seasons, like the week days, weekend days, national celebration days, and tourism seasons. Without loss of generality, this paper proposes a pricing model which can be applied for different demand seasons and different hotels with diverse capacities, based on market segmentation by adopting a fixed demand function and a finite capacity of hotel rooms. The applicability of the model will be verified in the numerical section through different demands.

In order to describe this problem clearly, we get the projection of the demand curves in *poq* coordinate system as shown in Fig. 2. And consequently, all the discussions can be done in this coordinate system.

Suppose that the hotel segments her room market into n parts, with a corresponding appropriate room rate to each part, and the number of assigned rooms in each segment may different. The fixed cost per day for the hotel is denoted as F and the variable cost is β. The additional operational cost of each segment per day is K, which is used for keeping it separately from other segments, advertising and administering in it (Ladany, 1996).

When only one segment is used, the model is the same with the normal decision making without market segmentation, the demand function is $q = a_0 - f(p)$. We denote q_1 as the number of rooms signed to this single segment, and then the room price can be obtained from $p_1 = h(q_1) \equiv f^{-1}(a_0 - q_1)$. Hence, the profit from this segment is as follows:

$$\pi_1(q_1) = q_1 h(q_1) - F - \beta q_1 - K, \tag{1}$$

where $1 \le q_1 \le C$.

The optimal room number, q_1^*, can be obtained from the first-order condition as the classical newsvendor model:

$$\frac{\partial \pi_1(q_1)}{\partial q_1} = h(q_1^*) + q_1^* h'(q_1^*) - \beta = 0.$$

Since q_1^* may be a non-integer value, the hotel will select the up rounded or down rounded of q_1^* that will maximize the profit. Denote $R_1(q_1)$ as the maximum profit from a single segment with q_1 rooms. Consequently,

$$R_1(q_1) = \begin{cases} q_1 p_1 - \beta q_1 - F - K, & \text{if } q_1 < q_1^* \\ q_1^* p_1^* - \beta q_1^* - F - K, & \text{if } q_1 \ge q_1^* \end{cases}, \tag{2}$$

where $p_1 = h(q_1) \equiv f^{-1}(a_0 - q_1)$ and $1 \le q_1 \le C$.

Now we consider that the hotel holds two market segments, where Q_1 rooms are assigned to the first segment and Q_2 for the second one; and the revenue is shown in Fig. 3.

Lemma 1. *The demand curve of the hotel rooms in the second segment must across the point* $(p_1,0)$

Proof. This Lemma can be proofed by contradiction. First, we assume the demand curve is higher than the point $(p_1,0)$ as shown in Fig. 4a. From the illustration we can see that there is $\Delta Q_1 = a_1' - a_1$ demand has been satisfied by both the first segment and the second one. Hence this kind of curves doesn't reflect the choice

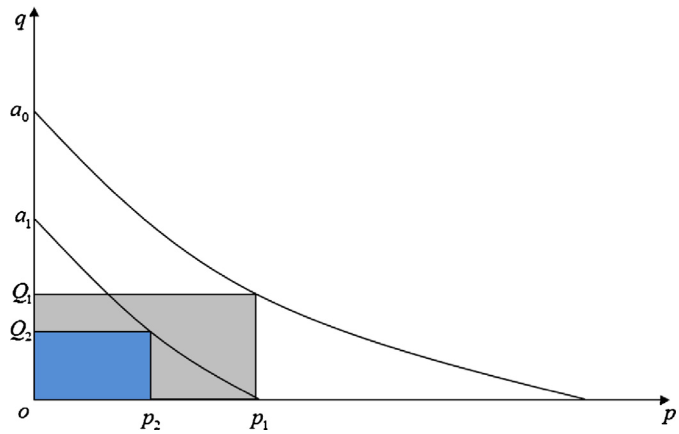


Fig. 3. Room prices and revenue obtained from two segments.

of the hotels in practice. Then we turn to the second case as shown in Fig. 4b, the demand curve is lower than the point $(p_1,0)$. Similarly with the first case, there is a demand $\Delta Q_2 = a_1 - a_1''$ missed under this kind of curves and this won't be the optimal choice for the hotels, neither. Consequently, the demand curve of hotel rooms in the second segment must across the point $(p_1,0)$. □

As shown in Fig. 3, the revenue obtained from two segments equals to the acreage of the two rectangles. Furthermore, according to Lemma 1 and the geometric transformation, the rectangles can be changed as Fig. 5 shows. In order to describe the model conveniently, we redefine $p = f^{-1}(a_0 - q)$ as $p = h_0(q)$, q_1 as the number of rooms assigned to the first segment, and q_2 as the total number of rooms assigned to this two segments, then there are $q_2 - q_1$ rooms assigned to the second one. Consequently, the profit obtained from two segments can be obtained as follows:

$$\pi_2(q_2) = (q_2 - q_1)f_0(q_2) - \beta(q_2 - q_1) - K + \pi_1(q_1), \quad (3)$$

where $q_1 \le q_2 \le C$.

Since the maximum profit from two segments is the sum of the maximum one from one segment and that of the second one. Hence, the maximal profit per day can be obtained by,

$$R_2(q_2) = \max\{(q_2 - q_1)f_0(q_2) - \beta(q_2 - q_1) - K + R_1(q_1)\}, \quad (4)$$

where $1 \le q_1 \le q_2$ and $2 \le q_2 \le C$.

After obtaining the optimal q_1 and q_2 from Eq. (4), the corresponding prices p_1 and p_2 can be obtained, and then the sale saturate market demand of the second segment is known from $a_1 = f(p_1)$ according to Lemma 1. Afterwards, the time dividing point of the two segments can be got from $a_1 = g(a_0,t)$.

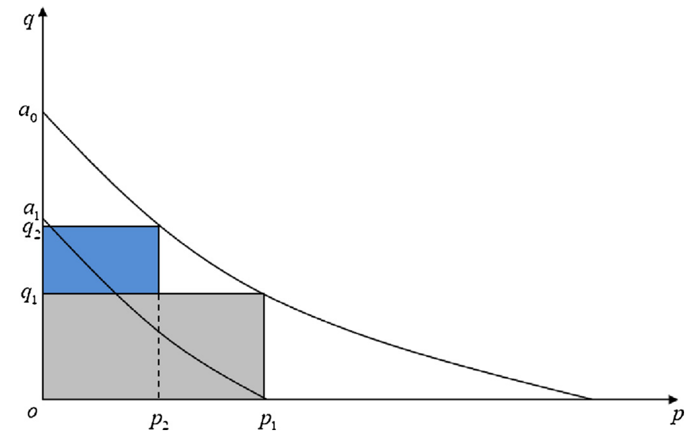


Fig. 5. Revenue of two segments after geometric transformation.

When the hotel holds n segments with her ORS, the total number of rooms assigned is q_n, and $q_n - q_{n-1}$ rooms assigned to the nth segment. Similarly to the scenario with two segments, the maximum profit from n segments can be obtained from,

$$R_n(q_n) = \max\{(q_n - q_{n-1})f_0(q_n) - \beta(q_n - q_{n-1}) - K + R_{n-1}(q_{n-1})\}, \quad (5)$$

where $n \le q_n \le C$.

Obviously, the difficulty of the pricing strategy is how to determine the room number and corresponding price of each segment. Hence, a solution methodology to solve this problem is provided in the next section.

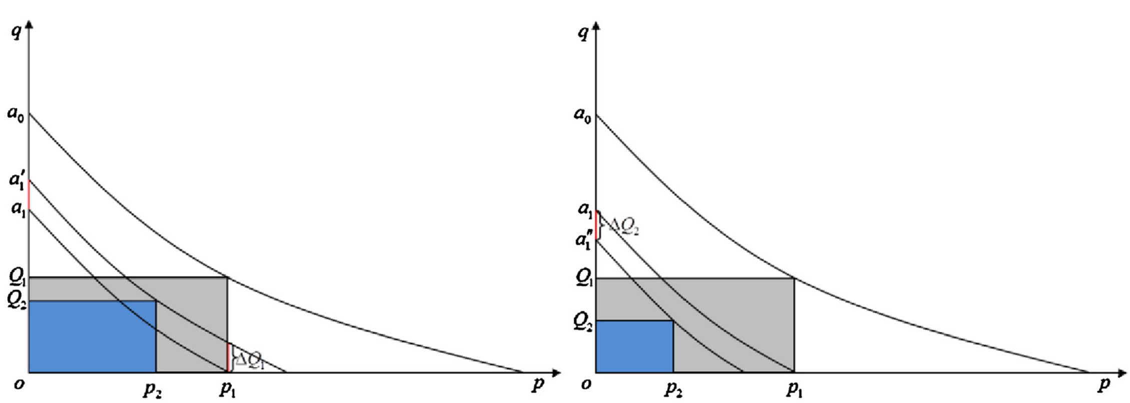
4. Solution methodology

This section gives the solution methodologies of the optimal dynamic pricing strategy of the service products. Because the solution depends on the demand curve heavily, we first give the solution for the linear case and then the solution methodology for the nonlinear case through a dynamic programming model.

4.1. The linear case

For the linear case, the following theorem gives us a convenient way to get the optimal solution.

Theorem 1. *For the linear case, $q = a_0 - bp$, the optimal pricing strategy for n segments must satisfy,*



a. The curve is higher than the point b. The curve is lower than the point

Fig. 4. Two cases of the demand curve does not across the point $(p_1,0)$.

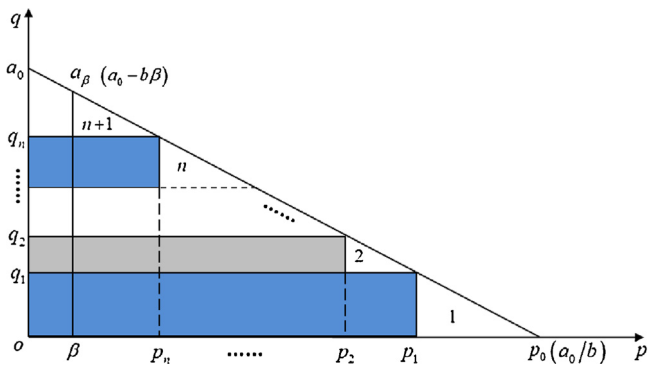


Fig. 6. Total revenue from n segments.

(1) if the capacity of the hotel rooms is big enough, that is $C \geq a_0 - b\beta$, there is

$$p_i^* = \frac{(n+1-i)a_0 + b\beta i}{(n+1)b}. \tag{6}$$

The corresponding number of rooms in each segment is $q_i^* = (a_0 - b\beta)i/(n+1)$. And the maximal total profit is $n(a_0 - b\beta)^2/(2b(n+1))$;

(2) if $C < a_0 - b\beta$, then there is

$$p_i^* = \frac{(n+1)a_0 + iC}{(n+1)b}. \tag{7}$$

The corresponding number of rooms in each segment is $q_i^* = iC/(n+1)$. And the maximal total profit is $nC^2/(2b(n+1))$.

Proof. Here we only provide the proof of the first part since their similarity. From the previous analysis, the n segments can be presented as Fig. 6 shows. Then the total potential profit when there are $n \to \infty$ market segments is the acreage of the triangle $a_\beta \beta p_0$, denoted as $A = (a_0 - b\beta)^2/(2b)$. When n is a finite integer, the profit from n segments is the total potential profit minus the marginal income as shown in the $n+1$ small triangles, that is $R_n = A - \sum_{i=1}^{n+1} A_i$, where A_i is the acreage of the ith small triangle. What's more, from Chebyshev's Sum Inequality (Gradshteyn and Ryzhik, 2000), there is $\sum_{i=1}^{n+1} A_i \geq A/(n+1)$, and the equal mark can be achieved if and only if $q_i - q_{i-1} = q_{i+1} - q_i$ for all $i = 1, \ldots, n$, where $q_0 = 0$ and $q_{n+1} = a_0 - b\beta$. Hence, there are $q_i^* = (a_0 - b\beta)i/(n+1)$ and $p_i^* = ((n+1-i)a_0 + b\beta i)/((n+1)b)$. □

From Theorem 1 we can get that the additional profit from the segments is $(Min\{C, a_0 - b\beta\})^2/(2b(n+1)(n+2))$ when the number of market segmentations increased from n to $n+1$. Then, respect to the operational cost of each segment, the optimal number of market segments, n, must satisfied,

$$\frac{(Min\{C, a_0 - b\beta\})^2}{2bn(n+1)} > K \geq \frac{(Min\{C, a_0 - b\beta\})^2}{2b(n+1)(n+2)}. \tag{8}$$

After finding the optimal number of market segments, the corresponding price and room number in each segment, the starting time of each segment can be obtained as follows. According to Lemma 1, for $i \geq 2$, we know the demand curve in the ith segment must across the point $(p_{i-1}, 0)$, hence, we have $a_i = bp_{i-1}$. Then from the relationship between a_t and a_0, $a_t = g(a_0, t)$, the starting time can be found. We can know the starting time of the ith segment. And similarly, all the lead times of each segment can be obtained easily.

4.2. The non-linear case

For the non-linear case, Theorem 1 does not work anymore. To solve this problem, a dynamic programming algorithm with N_k is described.

First, we denote k as the stage which is corresponding to the kth segment, q_k as the total room number in the first k segments, and $R_k(q_k)$ as the maximal profit gained from stage q_k at stage k. $N_k(q_k)$ is the decision variable at this stage. And furthermore, the state transfer function is $q_k = N_k + q_{k-1}$.

Afterwards, from Eq. (5) we get the recursive function as,

$$R_k(q_k) = R_{k-1}(q_{k-1}) + (q_k - q_{k-1})f_0(q_k) - \beta(q_k - q_{k-1}) - K, \tag{9}$$

where $R_0(0) = 0$, $q_0 = 0$ and $N_0 = 0$.

Then the maximal profit at stage $k > 1$ based on a known solution at stage $k-1$ can be obtained by solving:

$$R_k(q_k) = \max_{1 \leq N_k \leq q_n - k + 1} \{R_{k-1}(q_k - N_k) + N_k(f_0(q_k) - \beta) - K\}. \tag{10}$$

First let $R_k(q_k) = R_{k-1}(q_k - 1) + f_0(q_k) - \beta - K$, then for any $N_k \in (1, q_k - k + 1]$, if $R_k(q_k)\,|N_k > R_k(q_k)$, we have $R_k(q_k) = R_k(q_k)\,|N_k$. Consequently, we are seeking for $R_k^*(q_k)$ and N_k^* using the following pseudo code.

Initialize all $R_0(0) = 0$, $q_0 = 0$, $N_0 = 0$ and $R_0(N) = -\infty$ for $N > 0$.
For k = 1 to C
For $q_k = k$ to C
For $N_k = 1$ to $q_n - k + 1$
Update $R_k^*(q_k)$ and N_k^* with Eq. (10)
Return $R_k^*(q_k)$ and N_k^*

The detail of the algorithm is shown in Table 1 with a simple example when $C = 3$.

Although the quantitative relation in Theorem 1 no more exists in the non-linear case, the property that there is an optimal number of market segments leads to the maximal profit for the hotel is still true. That is to say, the function of the maximal hotel profit respect to the number of segments is a concave function. And the simulation in the next section makes this clear. Hence, we can stop the dynamic programming calculation when

$$R_{n-1}(q_{n-1}) \leq R_n(q_n) \geq R_{n+1}(q_{n+1}). \tag{11}$$

After getting the optimal segmentations for the hotel rooms, similarly with the linear case, using the relationship between the demand curves and the prices, $q_t = a_t - h(p)$, and that between a_t and a_0, $a_t = g(a_0, t)$, we can get the optimal pricing strategy respects to the reservation lead time.

Table 1
Detail of the dynamic programming algorithm with a 3 stages example.

	$q_k = 0$	$q_k = 1$	$q_k = 2$	$q_k = 3$
$k = 0$	$R_0(0) = 0$	$R_0(1) = -\infty$	$R_0(2) = -\infty$	$R_0(3) = -\infty$
$k = 1$		$R_1(1) = R_0(0) + T_{11}(1)$[a]	$R_1(2) = \begin{cases} R_0(1) + T_{12}(1) \\ R_0(0) + T_{12}(2) \end{cases}$	$R_1(3) = \begin{cases} R_0(2) + T_{13}(1) \\ R_0(1) + T_{13}(2) \\ R_0(0) + T_{13}(3) \end{cases}$
$k = 2$			$R_2(2) = R_1(1) + T_{22}(1)$	$R_2(3) = \begin{cases} R_1(2) + T_{23}(1) \\ R_1(1) + T_{23}(2) \end{cases}$
$k = 3$				$R_3(3) = R_2(2) + T_{33}(1)$

[a] T is the additional profit in each stage as $N_k(f_0(q_k) - \beta) - K$.

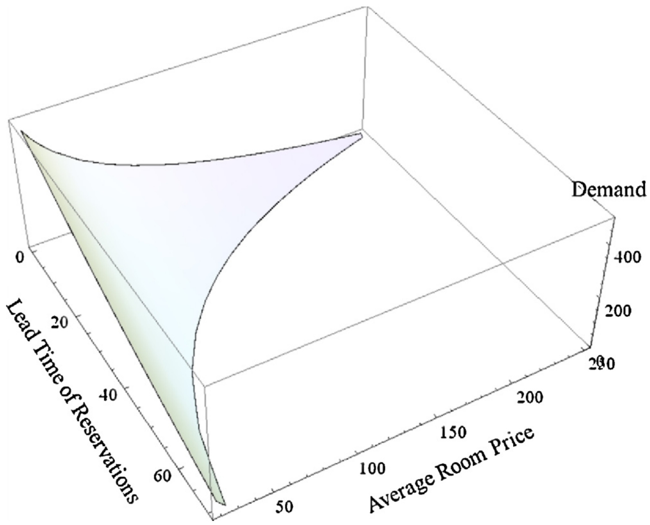


Fig. 7. Hotel room demand respect to the lead time and average room price.

5. Experiments for the non-linear case

In our numerical examples, we assume a hotel with the capacity of $C = 300$ rooms, where the fixed cost per day is $F = 10{,}000$ and the variable cost per day per room is $\beta = 10$, and furthermore, the additional operational cost for each segment per day is $K = 500$. Three demand levels are examined to show the applicability of our model: we first provide a base example to explain the decision process through a medium demand level in Section 5.1, and then a higher demand level in peak tourism season and a lower level corresponding to the tourism-off season are applied to show the applicability of the proposed pricing model in Section 5.2.

5.1. Base example

In this section, we adopt a medium demand level by assuming the demand function of the hotel at the target day is

$$q(t, p) = 1012e^{-0.008t} - 182 \ln p, \tag{12}$$

which obtained by assuming the curve passes through the points ($p = 50, q = 300$) and ($p = 150, q = 100$) at the target day, and the additional number of potential consumers respect to the lead time from the target day follows an exponential distribution, with the rate parameter $\lambda = 0.008$, which is widely used in the academic research (e.g., Ladany, 1996). As a result, the relationship between the number of potential consumers, a_t, and the lead time, t, can be described by the following equation:

$$a_t = 1012e^{-0.008t}.$$

The demand curve (12) is shown in Fig. 7.

The results of the solution through the dynamic programming model for stages $n = 1, 2, \ldots, 8$ are provided in Table 2. The results show that the maximal profit can be obtained by 7 segments, and the optimal solution is shown in Table 3.

The results tell that:

The pricing strategy based on market segmentation brings significant increase of the hotel profit. In Table 2, a 2-segment pricing decision brings more than double profits of the single segment, and a 3-segment strategy brings almost treble profit to the hotel.

A small number of market segments can lead to the full utilization of the hotel rooms. In Table 2, $q_n = 300$, i.e., every hotel room is expected to make profit for the hotel, when $n \geq 3$.

Table 2
Results of the dynamic programming calculations.

Stage	The optimal number of rooms assigned to each segment[a] and the corresponding price and lead time																								Maximal profit at stage n
	1st segment			2nd segment			3rd segment			4th segment			5th segment			6th segment			7th segment			8th segment			
n	q_1	p_1	t_1	q_2	p_2	t_2	q_3	p_3	t_3	q_4	p_4	t_4	q_5	p_5	t_5	q_6	p_6	t_6	q_7	p_7	t_7	q_8	p_8	t_8	
1	165	104.99	0																						5173.02
2	104	146.79	0	257	63.33	13.55																			11385.7
3	73	174.05	0	167	103.84	9.36	300	50.00	22.54																14617.1
4	54	193.20	0	118	135.92	6.85	197	88.06	15.49	300	50.00	27.06													16239.1
5	43	205.24	0	92	156.80	5.43	148	115.27	11.91	216	79.33	19.76	300	50.00	30.00										17058.0
6	35	214.46	0	74	173.10	4.40	118	135.92	9.49	169	102.71	15.49	228	74.27	22.84	300	50.00	31.90							17457.6
7	30	220.44	0	63	183.88	3.76	99	150.88	8.03	139	121.11	12.87	185	94.06	18.47	238	70.30	25.23	300	50.00	33.51				17610.1
8	26	225.33	0	54	193.20	3.25	85	162.95	6.85	119	135.18	10.96	156	110.31	15.63	198	87.58	20.92	245	67.65	27.21	300	50.00	34.64	17604.9

[a] For $i \geq 2$, the number of rooms assigned to the ith segment is $q_i - q_{i-1}$.

Table 3
The optimal solution of the pricing strategy based on market segmentation.

Segment	Number of rooms assigned to each segment	The corresponding price	The lead time (day)
1	30	220.44	0
2	63–30 = 33	183.88	3.76
3	99–63 = 36	150.88	8.03
4	139–99 = 40	121.11	12.87
5	185–139 = 46	94.06	18.47
6	238–185 = 53	70.30	25.23
7	300–238 = 62	50.00	33.51

Table 4
The optimal pricing strategy in different demand seasons based on market segmentation.

Demand season	Segment	Number of rooms	Room price	The lead time (day)
Peak tourism seasons (higher demand)	1	28	279.51	0
	2	30	243.57	3.51
	3	32	210.32	7.38
	4	34	179.95	11.64
	5	38	151.16	16.34
	6	41	125.25	21.80
	7	46	101.42	27.98
	8	51	80.26	35.30
Tourism-off seasons (lower demand)	1	34	149.31	0
	2	38	118.76	4.27
	3	43	91.66	9.22
	4	50	67.82	15.08
	5	60	47.25	22.24
	6	75	30.07	31.43

The optimal number of market segments is small, $n^*=7$ in this example and 5-segment strategy can provide a near optimal solution for the problem. While when $n>7$, the profit of the hotel decreases since the increased revenue cannot cover the operational cost for implementing the segment.

Table 3 shows that, under this pricing policy, the consumers can get at least a 30% discount if they make their reservations ten days before check-in. Furthermore, customers can receive more than 70% discount if they can arrange their schedule one month ahead.

In summary, this pricing policy leads to win–win equilibrium for service providers and consumers through bringing the providers full utilization of their service capacities and providing the customers considerable price discounts.

5.2. Optimal decisions in different demand seasons

In order to show the applicability of the proposed pricing model in different demand seasons, this section considers two demand scenarios, a higher room demand level in the peak tourism seasons and a lower room demand in the tourism-off seasons than that examined demand in the base example, for the same hotel.

According to Eq. (12), the demand functions of the two scenarios are defined as follows:

$$q_H(t,p) = 1256e^{-0.008t} - 218\ \ln\ p,$$

$$q_L(t,p) = 865e^{-0.008t} - 166\ \ln\ p,$$

which are determined by ($p=80$, $q=300$), ($p=200$, $q=100$) and ($p=30$, $q=300$), ($p=100$, $q=100$), respectively.

Using the solution methodology provided in Section 4.2, the optimal numbers of segments are $n^*=8$ for the peak tourism season scenario and $n^*=6$ for the off season one. The optimal solution of room allocations and pricing sets for the both scenarios are given in Table 4.

The results keep in line with those in the base example:

The results show that the pricing model proposed in this paper can be applied in different situations without any loss of applicability.

A small number of market segments leads to the maximal profit for the hotel in both peak tourism seasons and tourism-off seasons.

Whether in the peak seasons or in the off seasons, the consumers who make reservations fortnight in advance will receive a room rate discount no less than 30%.

6. Conclusions, limitations and future research

6.1. Findings and managerial insights

This paper studies the dynamic pricing strategy in using of online reservation systems for the service products. With a hotel as an example, both the linear case and non-linear case of the demand functions are analyzed.

In the linear case, we give the solution under the help of Chebyshev's Sum Inequality. While for the non-linear demand scenario, a dynamic programming model is adopted to solve the problem, which may more practical for the service providers. The results suggest that the market segmentation is benefit for the profit of the service providers, and there is a unique optimal segment-number which leads to the maximal profit. The numerical results in the non-linear case illustrate that if the number of segments is larger than the optimal one (e.g., $n^*=7$ in the base example), the total profit decreases. This is because the additional profit brought by the added segment cannot cover the additional operational cost for this segment.

The dynamic pricing strategy based on market segment, which operates through online reservation systems, is a win–win policy that benefits for both service suppliers and also the consumers. The numerical results tell that the pricing strategy can bring the service providers full utilization of their service capacities and provide the consumers considerable price discounts. Table 2 shows that the pricing policy can bring more than treble profit for the hotel, and Tables 3 and 4 show that the consumers may get a 50% discount if he made a reservation two weeks before the target day.

6.2. Limitations and future research directions

This paper is limited by some necessary limitations which could be fruitfully extended into plentiful interesting directions for future studies. Firstly, we assume the demand curve at time t can be obtained by the translation of the demand curve at the target day, i.e., all the demand curves with different lead time are with the same shape. That is to say, all the potential consumers are with the homogeneous sensitivity co-efficiency about the room price. Then how will the dynamic pricing strategy be when the consumers have different sensitivities at different time before the target day? Secondly, not all the consumers only stay in the hotel for one day; many consumers need a long-term stay, like two nights or more. Hence, the dynamic pricing strategy may update by combining advance booking with long-term stay. Thirdly, there may be some consumers make a cancelation before the target day or no-show at the appointed date. Consequently, a dynamic overbooking strategy may be adopted to fix this problem. These extensions would yield interesting insights, although there may be more challenges.

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