A Study of Dynamic Pricing Strategies for Cooperation between Cruise Lines and Travel Agencies

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Abstract. With the continuous development of our leisure tourism industry in recent years, cruise travel has gradually become the first choice of leisure consumers' vacation products. At the same time, with the development of the Internet and the continuous transformation of various marketing means, a single sales channel is no longer in line with the development trend of our cruise market. Therefore, we should strengthen our cooperation with travel agencies and expand the sales channel of cruise lines, which has become an important way for cruise companies to obtain higher earnings. In this paper, cruise cabins are sold by cruise companies, OTAs, and traditional travel agencies, and a dynamic pricing model is established to maximize the profit of cruise companies. MATLAB software is used to simulate and analyze the examples, and the dynamic prices of different sales channels are calculated to provide a basis for the formulation of cruise companies' pricing strategies.

Keywords: cruise lines; travel agencies; cruise cabin; dynamic pricing.

1 Introduction

Since the maiden voyage of the Elangona in 2006, the Chinese cruise market has begun to develop rapidly, becoming the second largest cruise market in the world in 2017. As the domestic cruise market has matured, a single sales channel has long ceased to meet the development of China's cruise market, and the multi-channel sales model has gradually emerged a bit.The rapid development of the cruise ship industry has led to much attention being paid to its revenue management. For cruise ship pricing, Sun et al. [1] analyzed the general pricing model of the North American cruise market and proposed a two-stage dynamic pricing model for maximizing the revenue of cruise lines in a limited time in the future. Aidin et al.[2]established a three-stage price discrimination model to analyze tourist attributes to 2020achieve changing demand and cabin allocation in each class. Zhao et al.[3]combined the characteristics of cruise ship operations, established an integer programming model, and used the EM algorithm to solve it. For the multi-channel sales of cruise ships, Zeng et al.[4]constructed a multi-party game sales strategy decision model for three cruise ship ticket sales channels and analyzed that the selection of sales channels is influenced by multiple factors. Guo et al.[5] constructed a planning model to optimize the input amount of direct sales channels to provide a feasible method for cruise companies. From the above studies, it can be seen that there are relatively few domestic and foreign studies on multi-channel revenue management of cruise ships. The innovation of this paper is that, firstly, most of the above literature is on revenue management of a single channel of cruise ships, while this paper considers the revenue management of multiple sales channels

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of cruise companies, which is more realistic; secondly, different cruise cabins are sold in different channels for different types of tourists, and the optimal price of each channel is determined dynamically; thirdly, the introduction of the stage conversion node parameter, which is conducive to the final stage of the cruise company's decision-making price change and improve the cruise company's revenue.

2 Model formulation

2.1 Problem description and model assumptions

A cruise line has X cruise tickets of the same type, which will be sold through different channels, and the ticketing time is T. It will be divided into several time periods, and considering the characteristics of the cruise ticket buying group, it is stipulated that only a group of m tourists in each time period will make a joint decision to buy the tickets, and considering the relationship between the cruise ticket price and the number of passengers, they will classify their tickets into j categories and make the following assumptions:(1) Since cruise passengers are mostly leisure travelers, it is assumed that there are no refunds or no-shows.(2) Life-saving cabin restrictions are not considered.(3) All ages are required to buy tickets and the cabin is for two.

2.2 Pricing Model

When only one channel sells cruise tickets, so that the price cruise tourists are willing to pay in purchasing a cruise cabin obeys the cumulative distribution, denoted by $F(*)$, and the cruise cabin price q_t obeys the uniform distribution on $[P_{\min}, P_{\max}]$. When the price cruise tourists are willing to pay is less than the price of the cruise cabin for sale, tourists will choose to buy it, and then its demand function can be expressed as $D_t(q_t) = M_t[1 - F(q_t)]$,its linear demand function can be obtained as $D_t(q_t) = \frac{P_{\max}}{P_{\max} - P_{\min}}(M_t - \frac{M_t}{P_{\max}} q_t)$, i.e. $D_t(q_t) = a - bq_t$, $\frac{a}{b} = P_{\max}$,Where M_t is the market size, $P_{\min}$ and $P_{\max}$ are the minimum and maximum values of cruise cabin prices. When selling tickets through multiple channels, the probability of choosing the channel is a linear function of the price of each sales channel[6], and considering the mutual influence between the channels, the probability of tourists choosing to buy cruise tickets in the channel can be $\lambda_i(p_i,t) = a_i - b_i q_{ij} p_i + \sum_{k \neq i, k \in I} r_{ik}(q_{kj} p_k - q_{ij} p_i)$ where q_{ij} is the discount given by channel i to the jth category of tourists with $\frac{a_i}{b_i} = P_{\max}$, $r_{ik} = r_{ki}$ since the cruise line has three sales channels, and r_{ik} is the coefficient of influence of channel i and k prices. For the number of remaining cruise slots $x = X, X - m, \cdots, 0$, the ticketing cut-off time $t = T, T - 1, \cdots, 0$, define $V_t(x_t)$ as the cruise line's expected revenue function

$$V_t(x)=\max_{p\in D}\{\sum_{i=1}^{3}\lambda_i[(1-\alpha_i)(\vec{p}_i^{\theta}\cdot m\vec{E}_j)+V_{t-1}(x-m)]+(1-\sum_{i=1}^{3}\lambda_i)\cdot V_{t-1}(x)\} \tag{1}$$

where α_i is the commission rate of the channel i; $D=\{p_i|p_i\geq 0,\lambda_i(p_i)\geq 0\}$ is a non-negative constraint on the price and probability. The boundary conditions are $V_0(x)=0$ $0\leq x\leq X$; $V_t(0)=0$ $0\leq t\leq T$ The first boundary condition is that the cruise line will not make any decision when the ticketing time closes; the second boundary condition is that the cruise line gains zero when the remaining amount of tickets is zero; it also needs to satisfy when $m<x_t$, $m=0$ and $x_{t-1}=x_t$, that is, the cruise line will refuse to sell when the number of remaining cruise tickets is less than the number of arrivals m. $\vec{p}_i^{\theta}\cdot m\vec{E}_j$ is the number of tourists when the cruise line gives the class j discount. Under the above conditions, the actual pricing strategy is considered, and parameter β is introduced to describe the relationship between the remaining time t and βT. When $t\geq\beta T$, this is the first stage: each sales channel sells discounted slots. Otherwise it is the second stage.

3 Expected revenue and optimal pricing strategy analysis

Definition $\Phi_t(x,p_i)=\sum_{i=1}^{3}\lambda_i[(1-\alpha_i)\theta_{ij}mp_i-(V_t(x)-V_t(x-m))]$ is the marginal revenue function of $V_t(x)$ with respect to t.

Theorem 1 The marginal revenue function $\Phi_t(x,p_i)$ has a maximum value with respect to the Hessian matrix of price 2.

$$H_{\Phi}=\begin{pmatrix}-\theta_{1j}^2B_1 & \theta_{1j}\theta_{2j}\rho_{12} & \theta_{1j}\theta_{3j}\rho_{13}\\ \theta_{1j}\theta_{2j}\rho_{21} & -\theta_{2j}^2B_2 & \theta_{2j}\theta_{3j}\rho_{23}\\ \theta_{1j}\theta_{3j}\rho_{31} & \theta_{2j}\theta_{3j}\rho_{32} & -\theta_{3j}^2B_3\end{pmatrix} \tag{2}$$

Proof: in the second stage, when $t<\beta T$, the cruise ship channels do not provide discount cabins, due to the fact that coefficient matrix H_{Φ_1} of (3) is the main diagonal possession matrix and the main diagonal is negative, then H_{Φ_1} is negative definite and the marginal revenue function for there is a maximum; in the first stage, when $t\geq\beta T$, the channels give different discounts to tourists, its first-order order master sub formula is $H_{\Phi}^1=-\theta_{1j}^2B_1<0$, its second-order master sub formula is $H_{\Phi}^2=\theta_{1j}^2\theta_{2j}^2(B_1B_2-\rho_{12}^2)>0$, and its third-order master sub formula is $H_{\Phi}^{3}=q_{1j}^{2}q_{2j}^{2}q_{3j}^{2}(B_{3}r_{12}^{2}+B_{2}r_{13}^{2}+B_{1}r_{23}^{2}-B_{1}B_{2}B_{3})$, $\left|H_{\Phi_1}\right|>0$ that is $H_{\Phi}^{3}>0$. Therefore, the marginal revenue has a maximum value.

Theorem 2 The optimal price has the following properties:(1) When $\overline{p}_1<\hat{p}_1$, $p_2\geq p_{-23}(\overline{p}_1)$, $p_3\geq p_{-32}(\overline{p}_1)$, the optimal pricing for each channel is $p^{*}=(\overline{p}_1,p_{-23}(\overline{p}_1),p_{-32}(\overline{p}_1))$, when the cruise line's own sales channel is opened.

(2) When $\overline{p}_1<\hat{p}_1$, $\overline{p}_2<\hat{p}_2$, $p_3\geq p_{-3}(\overline{p}_1,\ \overline{p}_2)$, the optimal pricing of each sales channel is $p^{*}=(\overline{p}_1,\overline{p}_2,p_{-3}(\overline{p}_1,\ \overline{p}_2))$, when only the cruise line self-sales channel and OTA are opened.(3) When $\overline{p}_1<p_{-1}(\overline{p}_2,\overline{p}_3)$, $\overline{p}_2<p_{-2}(\overline{p}_1,\overline{p}_3)$, $\overline{p}_3<p_{-3}(\overline{p}_1,\overline{p}_2)$, the optimal pricing for each channel is $p^{*}=(\overline{p}_1,\overline{p}_2,\overline{p}_3)$, when all channels are opened.(4) When $p_1\geq\hat{p}_1$, $p_2\geq\hat{p}_2$, $p_3\geq\hat{p}_3$,reach their optimal pricing of each channel $p^{*}=(\hat{p}_1,\hat{p}_2,\hat{p}_3)$, then close all channels.

Proof: (1) When $\lambda_1(p_{-12},t)=0$ and $\lambda_2(p_{-21},t)=0$ can be found, We can figure out the values of $p_{-12}(p_3)$ and $p_{-21}(p_3)$,where is the price for closing channels 1 and 2 and opening 3. When $p_1\geq p_{-12}(p_3)$ and $p_1\geq p_{-12}(p_3)$ arrive, when the cruise line will choose to close the self-selling channel and OTA and open only the traditional travel agency. (2)-(4) proof is similar to (1) proof and is not repeated here.

4 Algorithm description

Step 1: The cruise line decides whether to sell the cruise tickets.

Step 2: Determine the maximum price for channel based on historical sales data.

Step 3: Determine the value of the parameter in λ_i for the current time period. Calculate the optimal price based on formula (1).

Step 4: Update the range. When $p_i^{*}\leq p_{i\max}$, the price of the channel still takes a range of $[P_{i\min},P_{i\max}]$.when $p_i^{*}>p_{i\max}$, then there are $p_{i\max}=p_i^{*}$;

Step 5: $x=X-m$, $t=T-1$.Does not satisfy condition, turn the first step, otherwise stop calculation.

5 Example analysis

Now cruise ship D departs from Sanya, China to Xisha, there are 240 tickets for inside cabins for sale, this type of room in its official website. As can be seen from Table 1, Ctrip and offline travel agencies selling price of the highest historical selling price of inside cabins are 5980 yuan, 5780 yuan, 6180 yuan.

Table 1. Price of each channel voyage on the same route of cruise D

Time	The price of Self-marketing channel(yuan)	The price of OTA price(yuan)	The price of Travel agency price(yuan)
Jan.	5580	5500	5620
Feb.	5790	5630	5830
Mar.	5880	5690	5890
Apr.	5880	5730	5900
May	5890	5730	5970
Jun.	5950	5750	5970
Jul.	5980	5780	6180
Aug.	5980	5770	6000
Sep.	5980	5780	6000
Oct.	5890	5650	5890
Nov.	5760	5600	5730
Dec.	5680	5610	5700

At the same time, ticketing time T = 100, and the number of tourists arriving obey an approximately normal distribution, the cruise line cabin discount type into Three types $q_{i1} = 1$ $q_{22} = 0.9$ $q_{23} = 0.85$ $q_{32} = 0.95$ $q_{33} = 0.89$. In addition, the commission rates for different channels are $a_1 = 0$ $a_2 = 0.2$ $a_3 = 0.15$ .For intuitive understanding, the horizontal coordinate t in the calculation example represents the time of the start of ticketing, which is the opposite of the previous distance from the ticketing as of time t.

As can be seen from Figure 1, the full-price cabin price of each channel does not increase monotonically with the start time of ticketing, i.e., the cabin price of each channel does not decrease monotonically with the start time of ticketing and does not increase with the number of remaining tickets, and the result tests the rationality of the parameter b setting. Through calculation, dynamic pricing returns will be higher than normal pricing model. Therefore, as the number of remaining cruise slots decreases, cruise lines can increase their revenue by increasing the price of cruise slots in the final sale phase at the appropriate time stage of conversion.

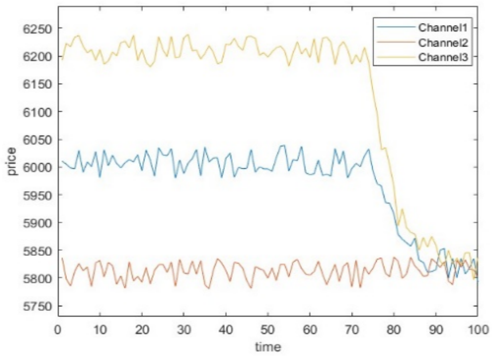

Fig. 1. The change of the best class price by channel

As can be seen from Figure 2, with the increase of the coefficient, the total revenue of the cruise line increases, that is, the earlier the cruise line chooses to enter the second stage, the more revenue it obtains, but the higher price will affect the probability of tourists choosing the voyage, the premise assumed in this paper is that at a specific point in time tourists must come to buy cruise tickets, which is the reason for the above conclusion as well as the following image, and finally combined with the actual cruise cabin price will affect the choice of tourists, the cruise line at least choose to be less than half the total time from the cut-off time before choosing not to offer discounts, so as to analyze the changes in the stage of the cruise line offering discounts.

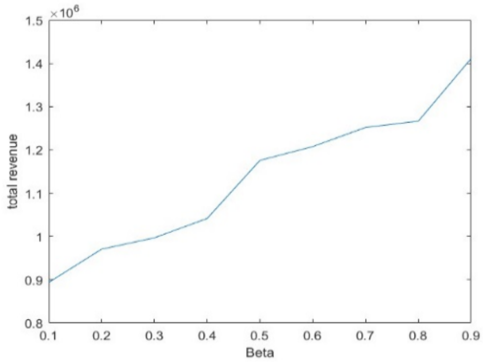

Fig. 2. Plot of phase change parameters versus total revenue

For this reason should be within $[0.1T, 0.5T]$, determine the appropriate value b, combined with the greater the slope, the impact on the probability of tourists to choose the voyage to analyze, for the remaining four time periods, [0.2T,0.3T], [0.3T,0.4T] slope is small, [0.3T,0.4T] earnings are higher, and more obvious changes have occurred; if at this time the cruise line has reached revenue satisfaction, it can directly enter the non-discount period, but the earnings stability is weaker. The revenue of [0.2T,0.3T] is less than [0.3T,0.4T] but the stability is better, so you can choose to enter the non-discount period in order to enter the non-discount period.

6 Concluding remarks

This paper takes the dynamic pricing of the same class of cruise seats in three sales channels as the entry point, comprehensively considers the relationship between the number of tourists and discount, establishes a multi-channel dynamic pricing model for cruise ships, takes a cruise company as the background to conduct a case study, which not only provides a reference for cruise companies to expand their sales channels, but also greatly improves their economic benefits.

The study found that, first, cruise companies should broaden their sales channels and adopt a multi-channel dynamic pricing sales model, which can both improve their revenue and control the changes in the number of cabins in stock to promote the sustainable development of the cruise market; second, cruise companies tend to attract tourists with preferential prices, but when ticketing is about to stop, cruise companies will choose to raise their prices to obtain revenue, and the analysis concluded that it is more appropriate to stage a switch between 0.2T and 0.3T near the time when ticketing ends. Third, if you want to improve the revenue of one or several channels, you can raise the price of other channels to the critical point, which can make other channels in a closed state, and the probability of tourists choosing the current channel to buy a cruise cabin will be greatly enhanced, so as to achieve the purpose of improving the revenue of one channel This is to increase the revenue of one or several channels. There are some shortcomings in this paper. This paper has certain shortcomings, only consider the same type of tickets in different channels of revenue, combined with different types of tickets in different channels of sales would be more appropriate to the actual situation.

However, this paper also has some shortcomings. The price of cruise tickets is not only affected by channels and the number of tourists, but is also related to the type of shipping space and specific market conditions. In the future, the above factors can be combined with the multi-channel sale of cruise tickets to conduct a deeper study.

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