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Optimal room charge and expected sales under discrete choice models with limited capacity☆

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ABSTRACT

In this paper, we introduce a model that incorporates features of the fully transparent hotel booking systems and enables estimates of hotel choice probabilities in a group based on the room charges. Firstly, we extract necessary information for the estimation from big data of online booking for major four hotels near Kyoto station.[1] Then, we consider a nested logit model as well as a multinomial logit model for the choice behavior of the customers, where the number of rooms available for booking for each hotel are possibly limited. In addition, we apply the model to an optimal room charge problem for a hotel that aims to maximize its expected sales of a certain room type in the transparent online booking systems. We show numerical examples of the maximization problem using the data of the four hotels of November 2012 which is a high season in Kyoto city. This model is useful in that hotel managers as well as hotel investors, such as hotel REITs and hotel funds, are able to predict the potential sales increase of hotels from online booking data and make use of the result as a tool for investment decisions.

1. Introduction

Hotel revenue management is an important issue not only for hotel managers, but also for hotel REITs and tourism funds who invest in hotels and engage in the management in order to increase profitability from the properties. By the revenue management, they are able to know how they operate the hotels in order to increase the revenues. For the investors in hotels, by knowing the sizes of potential sales increase, the revenue management can also be used as an investment decision making tool. Taking this into account, we consider maximization of expected sales of a certain room type of hotels in a group in the same area by solving for optimal room charges. The model incorporates random choice of hotels by customers who visit an online hotel booking website. Then we use big data of online booking for major four hotels near Kyoto station for the estimation, which were collected from a Japanese booking website by National Institute of Informatics. They include hotel names, accommodation plans with room types, remaining numbers of the plans available for booking, and prices of the plans for fourteen days booking periods prior to check-in dates. They are meaningful since those include more detailed information than the financial statements which are usually undisclosed. We first extract necessary information from the data under some suitable assumptions so that it can be used to estimate the parameters of the model.

For literatures on online hotel booking systems, Wang et al. (2015) investigates relations between the quality of hotel websites and customers' online booking intentions. Noone and Mattila (2009) studies how the two ways of rate presentation for multiple-day stays, the blended and non-blended presentations of best available rates, affect customers' willingness to book. Liu and Zhang (2014) examines factors for travelers to choose an online booking channel among hotel and online travel agencies websites. Casaló et al. (2015) studies effects of online hotel ratings by online travel communities, such as TripAdvisor, on booking behaviors of customers. Ladhari and Michaud

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(2015) investigates influences of online word of mouth in social network services, such as Facebook, on the choice of a hotel. Abrate et al. (2012) examines dynamic pricing strategies of 1000 European hotels. Viglia et al. (2016) analyses the impact of hotel price sequences on customers' reference price which is used to evaluate market prices.

For applications of discrete choice models to tourism research, Masiero et al. (2015, 2016), Nicolau and Masiero (2013), and Masiero and Nicolau (2012) use the mixed logit model for the analysis of choice behaviors of hotel customers. Masiero et al. (2015) investigates customers' willingness to pay for hotel room attributes within a single hotel property. Masiero et al. (2016) examines an asymmetric preference for hotel room choices based on prospect theory. Masiero and Nicolau (2012) analyses the determinants of individual price sensitivities to tourism activities. Nicolau and Masiero (2013) observes the effect of individual price sensitivities to tourism activities on on-site expenditures. Moreover, Viglia et al. (2014) investigates impact of customer reviews on preference for hotel choice by a rank conjoint experiment. Masiero et al. (2015) examines determinant factors of tourist expenditure for accommodation by a quantile regression.

Also, there are some other literatures on hotel revenue management by quantitative approaches. Quantitative revenue management has been studied mostly on online booking systems of airline tickets. For instance, Kimes (1989), Weatherford and Bodily (1992) summarize the methodologies. For hotels, Bitran and Mondschein (1995), Badinelli (2000) consider sales maximization of a single hotel. In particular, Bitran and Mondschein (1995) takes into consideration the case of multi-day stays, and Badinelli (2000) investigates dynamic room pricing where the optimal policy depends on the vacancy and the remaining days before the check-in date. Anderson and Xie (2012) is the first study that deals with the sales maximization of hotels in a group, taking into account choice behaviors of customers in online booking systems. Specifically, Anderson and Xie (2012) studies on opaque booking systems where the name of a hotel that customers try to book is concealed until the booking is done, assuming the nested-logit model for the customer choices among hotels in different areas and price ranges. For qualitative analysis on practices of hotel revenue management, see Baker and Collier (1999), Donaghy et al. (1995), Hanks et al. (1992), Kimes (1989), and Lieberman (1993).

While Anderson and Xie (2012) covers the opaque booking systems which are popular in the United States, the fully transparent booking systems, where customers consider booking by knowing names of the hotels, are common in Japan. This is because customers care for names and reviews of the hotels, since the quality of the services are dissimilar even among the same rank of hotels and some hotels differentiate themselves from the rivals by selling variety of accommodation plans which include options such as tickets for sightseeing facilities, recreation, and meals.

In the transparent booking systems, particularly in high seasons, as customers are only able to choose hotels offering available rooms, the limitation of the number of rooms that the rival hotels can offer is an important factor to be considered in modeling. On the other hand, in the opaque booking systems, choice categories, a pair of ratings and areas, are not exhausted as long as some of the hotels in the categories provide rooms. Hence we model the transparent booking systems, taking into account the limitation of the available number of rooms for the rival hotels. In the model, fully occupied hotels are excluded from the choice alternatives. We note that our model contains so called a waterfall structure as in collateralized debt obligations in finance. (See Gibson (2004) and Hull and White (2010) for details.)

Moreover, in contrast to the opaque booking systems where the daily changing pricing is a key to maximizing the sales, consistent pricing is important in the transparent booking systems. As Anderson and Xie (2012) points out, the frequent price changes and discounts in a booking period in the fully transparent booking systems may lose loyal customers of the hotel who book in advance thorough the direct selling channel at regular high prices. Therefore, our work aims to obtain one optimal room charge, which is unchanged through a booking period in the transparent booking systems, while Anderson and Xie (2012) deals with daily pricing in the opaque booking systems in the United States where hotels maximize their profits by selling out their rooms by discounting in several days before the check-in date.

The organization of the paper is as follows. Section 2 introduces the model that reflects choice behavior of customers in the transparent online booking systems. The model assumes a Poisson process for the frequency of visiting of customers and a nested logit model, as well as a multinomial logit model, with limited number of available rooms for hotels. An algorithm to calculate the expected sales under the model is also shown in this section. Section 3 provides numerical examples of the optimal room charge. Finally, Section 4 concludes. Appendices provide properties on the nested logit model in Section 2.1, and proofs of the theorem on existence of an optimal room charge in Section 2.2 and the lemma in Section 3.2.

2. Model and estimation

2.1. Model specification

In this subsection, we introduce the model that describe booking activities of customers in an online system who make a reservation for a certain type of room in a group of hotels. Let $\{1, 2, \ldots, M\}$ be check-in dates. First fix a check-in date m, $1 \le m \le M$. Let $[0, T]$ be a booking period for the check-in date, where 0 is the start date of the period and T is a check-in date. We fix the check-in date. Let $t \in [0, T]$ be a booking date. We assume that the total number of rooms booked during the period for the group for the check-in date follows a Poisson process $\{N_t^{(m)}\}_{0 \le t \le T}$ with intensity $\lambda^{(m)}$. We further assume the following.

- Fix the number of hotels in the group. Let $L \in \mathbf{N}$ be the number of hotels and we name the hotels from hotel 1 to hotel L.
- Let R_t^i, $(1 \le i \le L)$ be the number of rooms of hotel i booked until time t that satisfies

$$\sum_{i=1}^{L} R_t^i = N_t^{(m)}, \tag{1}$$

$$0 \le R_t^i \le q_i^{(m)}. \tag{2}$$

  Here $q_i^{(m)} \in \mathbf{N} \cup \{\infty\}$ is the maximum number of rooms available for booking for hotel $i (0 \le i \le L)$.
- Let $\gamma \in \Gamma := \Pi_{i=1}^{L}\{0, 1\}$ be the state of full occupancy. That is, 0 for the ith component of γ means that there is no available room for the hotel i, otherwise the hotel is available for booking.