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Price discount and capacity planning under demand postponement with opaque selling

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ABSTRACT

In this paper, we consider the opaque selling strategy of a firm that uses a price discount to induce demand postponement. Under demand postponement, the firm offers a price discount to advance customers in exchange for the option to fulfill their orders after the spot demand has been satisfied. Advance customers who take the discount commit their orders early, but the actual delivery time is chosen by the firm. In effect, the price discount enables the firm to create a capacity buffer for the spot demand. We formulate a two-stage stochastic program, and characterize the firm's optimal capacity and price discount decisions to maximize its expected profit. We find that the driver of demand postponement is that the option to postpone allows the firm to not only use less safety stock to hedge against the risk in the spot demand, but also reduce capacity waste. In addition, the firm might gain from the potentially lower capacity cost for postponed demand. In the event that the advance demand information can be utilized to update the regular demand distribution, the firm can garner additional benefits from information updating through the early orders. Through numerical experiments, we demonstrate the significance of the value of demand postponement and information updating, and assess the impact of market conditions on the firm's optimal capacity and price discount decisions.

1. Introduction

The rapid advancement of information technology has changed the way the business world operates. For instance, many major Chinese travel agencies have moved their business online in recent years (e.g., Aoyou.com). While the addition of the online channel allows these firms to reach out to a larger customer base, it also amplifies the demand variance and operational risk, especially during holiday seasons with rush demand. As a result, matching supply and demand, a constant challenge faced by business executives, becomes even more demanding.

Commonly used matching strategies to deal with operational risk, as extensively reviewed by Tang [1], include supply management, demand management, product management, information management, etc. Under circumstances where demand is highly volatile, firms often use various demand management strategies to manipulate the uncertain demand dynamically so that the modified demand is better matched by supply.

Along the demand management line of research, innovative approaches like shifting demand across time, across markets, and across products have been studied. Of particular interest is the strategy of shifting demand across time. While it is common in many industries to use an advance booking discount program to enable a firm to shift customer demand earlier (e.g., Tang et al. [2]), we consider in this paper a different approach—demand postponement through price discount—for the firm to shift customer demand later. Under demand postponement, the firm offers a price discount to customers in exchange for the option to fulfill their orders at a later time. Customers who take the discount commit their orders early, but the actual delivery time of their orders is chosen by the firm. In effect, the price discount enables the firm to postpone these early orders to a later period, if necessary. From the perspective of the customers who order early, the product is opaque as the order fulfillment time is uncertain at the time of ordering.

The demand postponement strategy is made possible by exploiting customer heterogeneity regarding time and price, and thus generates a price discrimination effect. This is in the same spirit as the emerging opaque selling in the travel industry, such as last-minute sales and selling flexible products (see Jerath et al. [3] and Jiang [4] for specific examples). In opaque selling, service providers (e.g., airlines, hotels) aim to use opaque products to better utilize their limited capacity and maximize the revenue. In this paper, however, we take the perspective of an intermediary (e.g., a travel agency) that reserves and takes ownership of capacity (e.g., flight seats and hotel rooms) from service providers and sells them to two classes of uncertain demand in a holiday season. We investigate the price discount and capacity decision of the travel agency.

To motivate our model, consider the so-called Golden Week (GW) economy, an emerging phenomenon in the Chinese tourism industry. Recently, to stimulate the domestic tourism economy, the central

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government has set up two week-long national holidays: the National Day Golden Week in October and the Spring Festival Golden Week in January or February. These GWs see the largest flows of tourists, many of whom typically join group tours organized by travel agencies (Weisenthal [5]). Travel agencies reserve capacity from service providers in advance and then sell them in the form of bundled packages to tourists for profit (note that the capacity reservation here is similar to inventory acquisition, which is completely different from commission-based consignment sales). The capacity decision of travel agencies is a challenging one: if they do not reserve enough, they may lose the opportunity to capitalize on the high traffic and high markups during GWs (WantChinaTimes.com [6]). If they reserve too much, however, they may get hit by the large swings commonly observed in tourist demand. A local travel agency in Sanya city of southern China, for instance, is reported to have lost nearly ¥2 million due to average daily leftovers of 100 to 200 reserved hotel rooms during the 2010 Spring Festival GW (Lei [7]).

An effective strategy to help travel agencies hedge against the demand risk would be to exploit the customer heterogeneity. Since some tourists are flexible in terms of when to have their vacations, such losses can be largely reduced by selling opaque tour packages with flexible consumption time to better match the demand with capacity: suppose there are two demand classes X_1 and X_2, differing in the timing of reservation. The advance demand class X_1 makes reservations for the GW in the advance period (before the GW), which is before the travel agency commits capacity for the GW, while the spot demand class X_2 arrives in the regular period (the GW) before which the capacity decision has been made. The X_1 group consists of heterogeneous customers with different price sensitivities and time requirements. At the beginning of the advance period, the agency offers a price discount to the advance demand class X_1. Customers in this class who are more price sensitive but less time sensitive (e.g., college students with one-month winter vacation) take the discount and are willing to be postponed. Others in this class, i.e., advance customers with stricter time requirement, will pay the regular price and have their reservations guaranteed during the GW. Effectively, the agency uses a price discount to induce a fraction of the advance customers to agree to demand postponement. The orders from the spot demand class X_2 are generated from spontaneous purchases during the regular period. Therefore, this demand class exhibits little flexibility in terms of consumption date—once capacity shortage occurs, the excess demand in the X_2 class is lost.

The benefit of the postponable demand then becomes evident: the agency can take advantage of the postponable demand to reserve less capacity for the GW. In the event that the spot demand turns out to be large, the postponable demand can be indeed postponed to reduce stockouts of the spot demand. On the other hand, in case the spot demand realization turns out to be low, the postponable demand can be satisfied in the GW without postponement to reduce capacity waste. It is worth noting that our model framework is also applicable to a wide array of manufacturing settings when advance booking discounts are available. Readers are referred to Tang et al. [2] for more examples.

Essentially, the value of demand postponement accrues from the fact that the postponable demand can be used as a capacity buffer during the regular period. The tradeoffs, of course, are to balance the revenue forgone due to the price discount with the value of the option to postpone. In this paper, we use a stylized model to capture the above tradeoffs and evaluate the benefit of demand postponement through opaque selling. In the model, we formulate and solve a two-stage stochastic program to determine the firm's optimal price discount and capacity choice. We find that the driver of the demand postponement strategy is that the firm's flexibility to deliver the early orders at a later time enables it to not only use less safety stock to hedge against uncertainties in the spot demand, but also reduce capacity waste in the regular period. In addition, opaque selling offers the firm the opportunity to speculate the timing of satisfying the postponable demand: if the capacity cost is higher in the postponement period than in the regular period, the firm will build a capacity no less than the postponable demand in the regular period, and use the postponable demand as a capacity buffer for the spot demand; otherwise, the firm could benefit from building less regular period capacity than the postponable demand and intentionally satisfying part of the flexible orders in the postponement period at a lower cost. We make two major contributions to the literature: first, we integrate the demand postponement and opaque selling strategies based on observations from tourism practices. Second, we also incorporate the capacity decision into opaque selling. To the best of our knowledge, this is the first paper to endogenize the capacity decision in opaque selling in a newsvendor setting.

The remainder of this paper is organized as follows: Section 2 outlines related literature. We formulate the problem in Section 3 and then solve for the firm's optimal capacity choice and price discount in Sections 4 and 5, respectively. An extension to study the value of information updating is presented in Section 6. Section 7 presents numerical studies and additional managerial insights. The paper concludes in Section 8 with a brief discussion of future research directions. All proofs are provided in Appendix A.

2. Literature review

Our paper studies the opaque selling strategy in which a price discount is introduced to induce customers to make postponable orders. It is related to three streams of research, namely, research on demand management, inter-temporal pricing, and opaque selling.

2.1. Demand management

Our work is most closely related to the research stream broadly categorized as demand management (Tang [1]). Of particular relevance are papers considering shifting demand across time, either backwards or forwards. Iyer et al. [8] is the first to examine the benefit of shifting demand to a later time. They study a model to reduce overall inventory costs by preempting stockouts through demand postponement. Customers whose demands are postponed are paid a reimbursement per unit. However, in their model, customers behave in a passive manner and are forced to accept demand postponement made by the firms. In our paper, we consider the more realistic case where customers play an active role, i.e., they can self-select whether or not to participate in demand management through their choice of whether to take the price discount. In addition, unlike in their work, customers in our model are heterogenous in terms of their price and order fulfillment time sensitivity.

Using early order (or advance-purchase) discounts to shift demand earlier has also been widely studied in the literature. Weng and Parlar [9] are among the first to analyze a model in which the retailer offers a price discount in order to induce customers to pre-commit their orders. The discount helps lock in some customers, thus decreasing the variance of the total demand, as the market size is assumed to be fixed in their base model. They determine the optimal discount rate and the retailer's order quantity. Tang et al. [2] address a similar problem with different features. They consider two market segments, and emphasize the fact the early orders (advance bookings) provide information for the retailer to make a more accurate demand forecast. McCardle et al. [10] extend this work to include retail competition. The value of advance-purchase discounts is also studied by Xie and Shugan [11], who argue that advance-purchase discounts can be a win-win strategy for both some service providers and their customers, if there exists customer uncertainty about future valuations. In terms of the value of advance-purchase discounts, our model differs in two aspects: first, we focus on the role of early orders as a capacity buffer, rather than the use of them as advance information to reduce demand uncertainty. Second, while early orders in all the above papers require immediate fulfillment once the product becomes available, our model, in sharp contrast, considers the case where early orders induced by price discounts can be delivered at a later time.