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Decision Support

Duopoly game of callable products in airline revenue management

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ABSTRACT

This paper studies the capacity allocation game between duopolistic airlines which could offer callable products. Previous literature has shown that callable products provide a riskless source of additional revenue for a monopolistic airline. We examine the impact of the introduction of callable products on the revenues and the booking limits of duopolistic airlines. The analytical results demonstrate that, when there is no spill of low-fare customers, offering callable products is a dominant strategy of both airlines and provides Pareto gains to both airlines. When customers of both fare classes spill, offering callable products is no longer a dominant strategy and may harm the revenues of the airlines. Numerical examples demonstrate that whether the two airlines offer callable products and whether offering callable products is beneficial to the two airlines mainly depends on their loads and capacities. Specifically, when the difference between the loads of the airlines is large, the loads of the airlines play the most important role. When the difference between the loads of the airlines is small, the capacities of the airlines play the most important role. Moreover, numerical examples show that the booking limits of the two airlines in the case with callable products are always higher than those in the case without callable products.

1. Introduction

During the last three decades, the technology of revenue management has been used more and more widely around the world, and has played a significant role in improving the profits of corporations. As a result, this field has attracted much attention from scholars (e.g., Steinhardt & Gönsch, 2012; Hu, Caldentey, & Vulcano, 2013; Otero & Akhavan-Tabatabaei, 2015). In the airline industry in which the technology of revenue management is most widely used, airlines usually have to face two types of customers: low-valuation customers who accept low-fare tickets only but are willing to book in advance and high-valuation customers who are willing to buy expensive tickets but arrive just before the plane takes off. Usually, the airlines cannot forecast the demand from high-valuation customers with certainty or convince them to book earlier than the low-valuation customers. Thus, “despite heavy investment in sophisticated revenue management systems, airlines lose millions of dollars a year in potential revenue; both when low-fare bookings displace higher than expected high-fare bookings (‘cannibalization’) and when airlines fly empty seats protected for high-fare bookings that do not materialize (‘spoilage’)” (Gallego, Kou, & Phillips, 2008). Many kinds of mechanisms are proposed to hedge against demand uncertainty from high-valuation customers, e.g., overbooking (Aydın, Birbil, Frenk, & Noyan, 2012; Karaesmen & Van Ryzin, 2004), last-minute discounts (Ovchinnikov & Milner, 2012), flexible products (Gallego & Phillips, 2004), etc. All these mechanisms have shortcomings: overbooking adds operational complexity to management; last-minute discounts may induce the customers to wait rather than to book early; flexible products require that the customers are indifferent among the alternative flights. To avoid the above shortcomings, Gallego et al. (2008) proposed the concept of “callable products”, which refers to units of capacity sold to self-selected low-fare customers who willingly grant the airline the option to “call” the capacity at a pre-specified recall price. The concept of callable products does not add operational complexity and can be used together with other mechanisms.

Gallego et al. (2008) showed that callable products provide a riskless source of additional revenue for a monopolistic airline. In practice, airlines usually have to face other competitors. Seat allocation among different fare classes by one airline affects the demand and the optimal seat allocation of other airlines. Therefore, there are several questions to be addressed. In a competitive environment, does offering callable products still provide a riskless source of additional revenues? How does the introduction of callable products affect the capacity allocation decisions of the airlines? What is the order relationship between the booking limits

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under competition and those under monopoly? This paper aims to answer these questions.

This paper studies the capacity allocation game between duopolistic airlines which could offer callable products. We examine how the introduction of callable products affects the booking limits and the revenues of duopolistic airlines. It is shown that when the low-fare customers do not spill, offering callable products is a dominant strategy of both airlines and provides Pareto gains to both (In this paper, the word “spill” means that if either type of customer cannot be satisfied by one airline, the customers go to the other airline and can be recaptured by the other airline). When customers of both fare classes spill, offering callable products is no longer a dominant strategy and may harm the revenues of the airlines. Numerical examples demonstrate that whether the two airlines offer callable products and whether offering callable products is beneficial to the two airlines mainly depends on their loads and capacities (the load of an airline is the ratio of the average total demand of the airline to the capacity of the airline). Specifically, when the difference between the loads of the airlines is large, the loads of the airlines play the most important role. When the difference between the loads of the airlines is small, the capacities of the airlines play the most important role. Moreover, numerical examples demonstrate that the booking limits of the two airlines in the case with callable products are always higher than those in the case without callable products.

The rest of the paper is organized as follows. Section 2 reviews the literature on callable products and on revenue management game. Section 3 describes the key elements of the model. Section 4 presents a comprehensive model analysis. Specifically, Section 4.1 gives sufficient conditions for the existence and uniqueness of the Nash equilibrium; Section 4.2 examines the impact of callable products on the revenues of the airlines when there is no low-fare spill; Section 4.3 compares the booking limits under competition with those under monopoly; Section 4.4 conducts a sensitivity analysis of the booking limits with respect to the price parameters. In Section 5, we run numerical examples to examine the impact of offering callable products on the revenues and the booking limits of the two airlines, where both the low-fare and high-fare customers spill. Section 6 concludes the paper and points out directions for future research.

2. Literature review

Two streams of literature are related to our study: one is callable products, and the other is revenue management game.

Many forms of callable products have been used in various industries. Some companies use an option named “callback” to recall previously committed advertisement time by paying a predetermined amount. The callable concept is also used by Caterpillar to reduce the inventory risk of its dealers (Sheffi, 2005, pp. 229–231). Biyalogorsky, Carmon, Fruchter, and Gerstner (1999) showed that the use of overselling with opportunistic cancellations can increase expected profits in an airline context. Biyalogorsky and Gerstner (2004) demonstrated that contingent pricing can be used for sellers in response to demand uncertainty. In contingent pricing arrangements, price is contingent on whether the seller succeeds in obtaining a higher price within a specified period. It is shown that contingent pricing is profitable regardless of buyers’ risk attitudes, and that contingent pricing benefits buyers as well as sellers. Gallego et al. (2008) differed from and extended Biyalogorsky and Gerstner (2004) in the following ways. First, Biyalogorsky and Gerstner (2004) considered sales of a single unit of capacity and Gallego et al. (2008) extended the analysis to sales of multiple units. Second, Biyalogorsky and Gerstner (2004) assumed common willingness-to-pay among buyers, whereas Gallego et al. (2008) assumed that demand for callable products is uncertain and depends on the recall price. Gallego et al. (2008) showed that callable products provide a riskless source of additional revenue to a monopolistic airline. Biyalogorsky (2009) considered a model with strategic consumers who can decide when to show up in the market and investigated whether, in the face of strategic behavior by consumers, it can be profitable for sellers to use contingent pricing to induce the low-high arrival pattern typical in the airline industry. Elmaghraby, Lippman, Tang, and Yin (2009) examined a situation in which the firm offers both callable and non-callable units at different prices at any point in time. They showed that strategic customer behavior can render the customer to be worse off and the retailer to be better off. Therefore, more purchasing options do not necessarily benefit customers. Aydın, Birbil, and Topaloğlu (2016) developed single-leg revenue management models that consider contingent commitment decisions, where commitment option allows passengers to reserve a seat for a fixed duration before making a final purchase decision. We introduce the concept of callable products into a capacity allocation game between two airlines and examine its impact on the revenues and the booking limits of the two airlines.

The second stream of literature related to our study is revenue management game. Lederer and Nambimadom (1998) discussed how the entire airline network determines the routes and frequencies of flights when multiple airlines interact with each other. Using data on U.S. airline departure times from 1975, when fares were regulated, and 1986, when fares were not regulated, Borenstein and Netz (1999) empirically estimated the effect of competition on product differentiation. Richard (2003) analyzed the welfare consequences of airline mergers in terms of ticket price and flight frequency. The above research considers the competition between price, flight frequency and departure time, which is different from seat allocation competition as considered in this paper.

Netessine and Shumsky (2005) was the first published paper that places the seat allocation problem in a competitive framework and examines the seat inventory control problem. The analytical results demonstrated that more seats are protected for high-fare passengers under horizontal competition than when a single airline acts as a monopoly. Li, Oum, and Anderson (2007) showed the existence of an equilibrium booking strategy such that both airlines protect the same number of seats for the high fare and that the total number of seats available for the low fare under competition is smaller than the total number of seats that would be available if the two airlines were to collude. Li, Zhang, and Zhang (2008) extended Li et al. (2007) by incorporating the cost asymmetry of different airlines. While Netessine and Shumsky (2005) took the differentiation approach by assuming separate demand for each fare class offered by an airline, Li et al. (2007) and Li et al. (2008) chose the homogeneous market approach, i.e., two airlines face common market demand and the demand is split between the two airlines. The splitting rules of the demand in Li et al. (2007, 2008) are analogous to Rule 3 (Incremental Random Splitting) in Lippman and McCardle (1997) and generate demand that is independent or perfectly correlated, whereas the demand form in Netessine and Shumsky (2005) is more general as demand of different fare classes and different airlines can be partially correlated. We incorporate the concept of callable products into the framework of Netessine and Shumsky (2005) and examine its impact on the revenues and the booking limits of the two airlines.

Furthermore, Song and Parlar (2012) also studied the capacity allocation game between two airlines, where the demand form is similar to that in Netessine and Shumsky (2005). Song and Parlar (2012) took into account the penalty cost for each reservation of the transfer customers rejected by an airline. They used a nonnested model to approximate the original nested booking limit model and showed the existence of a unique Nash equilibrium in the noncooperative situation. Zhao, Atkins, (2002) made a major