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Decision Support

Dynamic pricing of primary products and ancillary services

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ABSTRACT

Motivated by the growing prevalence for airlines to charge for checked baggage, this paper studies pricing of primary products and ancillary services. We consider a single seller with a fixed capacity or inventory of primary products that simultaneously makes an ancillary service available, e.g. a single-leg flight and checked baggage service. The seller seeks to maximize total expected revenue by dynamically setting prices on both the primary product and the ancillary service. In each period, a random number of customers arrive each of whom may belong to one of three groups: those that only want the primary products, those that would buy the ancillary service if the price is right, and those that only purchase a primary product together with the ancillary service. A multi-period dynamic pricing model is presented with computational complexity only of order equal to the number of periods. For certain distributions, close to analytical results can be obtained from which structural insights may be gleaned.

1. Introduction

Consumers' expectations of what should be included in a purchased service vary greatly. At sporting or entertainment events, nobody expects to be served complementary food or beverages. Similarly, for car-rentals, hotels, and cruises (including all-inclusive), consumers generally have little expectation of receiving ancillary services, such as car insurance, GPS, meals or wifi, for free. However, at the opposite spectrum, for air travel, consumers are, or rather were, generally accustomed to receive complementary ancillary services (such as food and beverages, inflight entertainment, and the most prominent bone of contention: checked baggage service). For example, KLM, Air France, Delta Air Lines, American Airlines, and Air Canada now all charge for checked baggage on their respective 'domestic' European and North American economy class flights; KLM and Air France charges Euro15 for each piece, while Delta Air Lines, American Airlines, and Air Canada charge $25 and $35 for the first and second checked bag, respectively.[2] Even the US low-cost carrier Southwest Airlines, which markets flight service with two free checked bags charges for additional bags beyond two (Delta charges $125, American $150, Air Canada $100, and Southwest $50.) In sharp contrast to Southwest Airlines, the US ultra-low-cost carrier Spirit Airlines charges not only for checked baggage ($30) but also for carry-on baggage ($35).

Revenue from ancillary services such as baggage fees is of growing importance to the airline industry. For example, the total baggage fee revenues for US airlines has over the past six years grown to a multi-billion dollar industry; $464M (2007), $1,149M (2008), $2,729M (2009), $3,395M (2010), $3,361M (2011), $3,487M (2012), $3,350M (2013), $3,529M (2014).[3] Common arguments from airlines for charging for checked baggage are increasing fuel costs and to allow customers greater price flexibility. It is lesser known that many passenger airlines also transport cargo. Therefore low or zero baggage fees can represent an opportunity cost since fewer checked bags means more cargo space. The operational revenue from cargo transportation varies considerably among passenger airlines. For instance, for Delta and American, cargo represents only about 3% of the total operating revenue (AMR Corp, 2011; Delta Air, 2011), while reportedly for the top eight Asian airlines, cargo represents on average 30% of total revenue (Wong, Zhang, Hui, & Leung, 2009).

In this paper, we present a model of a single seller with a fixed capacity or inventory of homogeneous products who also provides an ancillary service, e.g. an airline that offers checked baggage service or a hotel that provides wifi. We consider a finite, discretized time-horizon over which the seller for each period seeks to set the prices of the primary items and ancillary service in order to maximize expected total revenue. We assume in each period a random number of customers arrive and that customers randomly belong to one of three

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[1] Tel.: +1 519 661 3867.
[2] On domestic Canadian routes, Air Canada charges $25 for the second.

[3] http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/airline_information/baggage_fees/index.html; accessed 2015-08-27.

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groups: those who only want a primary item and who would not consume the ancillary service even if it were free (Group 1), those who would potentially be willing to pay for both the primary item and ancillary service but who equally well would settle for just the primary item (Group 2), and those that only want a primary item as long as they also receive the ancillary service (Group 3). The objectives of the paper are: (1) to discuss how to derive optimal prices in order to maximize the expected total revenue, and (2) to analyze optimality conditions and the potential gain in charging separately for ancillary services versus a single charge for the bundle of the primary item and the ancillary service.

Given the importance and growing trend to charge for ancillary services, the paper makes several contributions. First, we provide a dynamic pricing model for evaluating the expected total revenue and propose an easy to implement algorithm for deriving the optimal dynamic prices. For the special case with uniform distributions and no capacity constraint, we derive close to closed form solutions. Second, we show that the optimal prices for the unconstrained capacity problem can often serve as a good approximation for the capacity constrained problem. Third, through numerical analysis based on the uniform distribution we show that the incremental gain in charging separately for the ancillary service is *higher* when the proportion of Group 3 type customers is *lower*. In other words, the incremental gain for airlines/hotels to impose ancillary fees is smaller when the proportion of customers with demand for the ancillary checked baggage/wifi service is high. Instead the largest incremental gain for a dual pricing strategy is when the majority of customers do not demand the ancillary service.

1.1. Literature review

Revenue Management (RM), formerly referred as Yield Management, has over the last forty years experienced a tremendous growth both in industry and academic research. For a general overview and background, see Bitran and Caldentey (2003); Boyd and Bilegan (2003); McGill and van Ryzin (1999); Talluri and van Ryzin (2004b). Although there is a rich literature on both capacity based and pricing based revenue management, as firms and industries develop innovative business solutions new research opportunities arise. A prime example is the sale of ancillary or secondary products and services - a relatively undeveloped research area.

The modeling framework presented in this paper contributes to three major components of the RM literature. First, we are considering dynamic pricing over time but extend the setting to include ancillary services. To the best of our knowledge this is the first paper to do so. Thus far the main focus has been on the dynamic pricing of the primary product, e.g. Zhang and Cooper (2009) who present a Markov Decision Process model for dynamic airline pricing. Second, we consider a stochastic customer arrival process. Traditionally, much of the literature regarding airline pricing or capacity allocation is based on Poisson arrivals of customers and formulated as a multi-period Network Revenue Management problem; see Gallego and van Ryzin (1997); Ch. 3 of Talluri and van Ryzin (2004b); Maglaras and Meissner (2006); Kunnumkal and Topaloglu (2010); Meissner and Strauss (2012). The general idea is to consider a number of small time periods where the probability of a single customer is small such that no more than one arrival is possible. Optimal decisions and total expected revenue are then found by recursively solving the Bellman equations. In this paper, we model the problem in a different manner. The benefit with our probabilistic approach is that it allows us to formulate the problem as a straightforward one dimensional optimization problem from which structural properties can be derived, e.g. uniqueness of the optimal prices, etc. Indeed, in special cases, we can obtain results that are close to closed form. Additional benefits is that our model allows for a general arrival process (not just Poisson), while not adding any computational complexity. Third, our model framework is based on an underlying customer choice model. Recent development within the RM literature include to directly model underlying consumer behavior or choices, see Talluri and van Ryzin (2004a) and chapters 2.6 and 7 of Talluri and van Ryzin (2004b); Kunnumkal and Topaloglu (2010); Chen and Homem-de-Mello (2010); and Cooper and Li (2012).

Two papers directly related to our research objective include Shulman and Geng (2012) and Allon, Bassamboo, and Lariviere (2011). Shulman and Geng (2012) analyze a duopoly game between two asymmetric firms that offer a *base good* and an *add-on* to a set of heterogeneous consumers. They segment the consumers into three groups: (i) a base group that does not buy the add-on, (ii) a group of knowledgeable consumers who buys the add-on if the add-on price is less than their willingness-to-pay, and (iii) a group of bounded rational consumers who were expecting to receive the add-on for free and who will only buy the add-on as long as their willingness-to-pay is higher than the total price. It is assumed all three consumer groups purchase a base good. Based on the assumption that consumers' willingness-to-pay is uniformly distributed, Shulman and Geng (2012) derive equilibrium prices for the base good and the add-on.

The paper by Allon et al. (2011) looks at the problem from a different perspective, namely from a coordinated social perspective of pricing the 'main service' and 'ancillary service' such that both consumer surplus and firm profit is maximized. They characterize, under both homogeneous and heterogeneous customer settings, when a *two-part tariff* versus *bundling* is socially optimal. They extend their results to a setting with multiple sellers and show that, at equilibrium, pricing of the ancillary service is set at the marginal cost of providing the service. One of the main differences between the modeling framework of Allon et al. (2011) versus our paper and Shulman and Geng (2012) is that customers do not have an explicit value for the ancillary service. Instead, Allon et al. (2011) assume all customers have a cost-driven likelihood for wanting/needing the ancillary service regardless of price (where the probability is decreasing in an effort level which indirectly depends on the price of the ancillary service).

Although our framework shares some common features with Shulman and Geng (2012) and Allon et al. (2011), there are five significant differences. First, while both Shulman and Geng (2012) and Allon et al. (2011) restrict attention to a single-period setting, we consider a multi-period dynamic pricing setting. Second, we consider the case of a possible capacity constraint on the number of primary items (i.e. base good or main service). In other words, we do not assume all consumers are guaranteed a primary item. Third, we extend the heterogeneity of consumers so that not all consumers are assumed to purchase a primary item if one is available. Fourth, although we include numerical illustrations based on the uniform distribution, our main discussion centers on a general modeling framework without any specific assumption regarding the distribution of the willingness-to-pay. Finally, our overall research objectives are different. For instance, Shulman and Geng (2012) seek to address how add-on pricing affects firm profits and consumer surplus in an asymmetric duopoly game with the three consumer groups. Implicit in their modeling framework and explicit in their results is that firms charge for the add-on. In contrast, one of our objectives is to analyze under what conditions a firm should charge for the ancillary item (or add-on). The motivation for this is to analyze the Delta/American Airlines versus Southwest Airlines business strategies of checked baggage service.

Framing the airline baggage fee problem as a *bundling* and *two-part tariff* problem, there is a vast literature spanning economics (e.g. the classic Oi (1971), and McAfee, McMillan, and Whinston (1989)), management science (e.g. Banciu, Gal-Or, & Mirchandani (2010)), and marketing (e.g. Essegaier, Gupta, & Zhang (2002)). From the four listed, the one most related to our paper is Essegaier et al. (2002), who considers a single-period pricing strategy of *access services* (e.g.