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Dynamic discrete choice model for railway ticket cancellation and exchange decisions

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ABSTRACT

The increasing use of internet as a major ticket distribution channel has resulted in passengers becoming more strategic to fare policy. This potentially induces passengers to book the ticket well in advance in order to obtain a lower fare ticket, and later adjust their ticket when they are sure about trip scheduling. This is especially true in flexible refund markets where ticket cancellation and exchange behavior has been recognized as having major impacts on revenues. In this paper, we propose an inter-temporal choice model of ticket cancellation and exchange for railway passengers where customers are assumed to be forward looking agents. A dynamic discrete choice model (DDCM) is applied to predict the timing in which ticket exchange or cancellation occurs in response to fare and trip schedule uncertainty. The problem is formulated as an optimal stopping problem, and a two steps look-ahead policy is adopted to approximate the dynamic programming problem. The approach is applied to real ticket reservation data for intercity railway trips. Estimations results indicate that the DDCM provides more intuitive results when compared to multinomial logit (MNL) models. In addition, validation results show that DDCM has better prediction capability than MNL. The approach developed here in the context of exchange and refund policies for railway revenue management can be extended and applied to other industries that operate under flexible refund policies.

1. Introduction

Ticket cancellation and exchange behavior has significant impact on the revenue management (RM) system (Iliescu, 2008). In flexible refund markets, passengers are inclined to book their tickets in advance in order to obtain lower fares, and to exchange/cancel the tickets when changes in their schedule intervene. Moreover, the use of internet as a major ticket distribution channel has affected the behavior of customers who have now better access to fare information, and are becoming more strategic in their choices. Reliable predictions in cancellation and exchange decisions are believed to enable analysts to derive more efficient overbooking and refund/exchange policies. RM applications to air transportation have demonstrated to significantly reduce the number of empty seats on flights for which there is actually a potential demand (Neuling et al., 2004). Existing literature on choice modeling for revenue management (RM) have mostly ignored temporal effects in individual decision making. Although static models enable analysts to address the dependence of demand on the set of products offered by the provider, they are unable to model forward looking agents, who would typically wait and see before making the final decision.

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In this paper, we propose a dynamic framework based on discrete choice models developed in the context of railway revenue management. Dynamic discrete choice models have been firstly developed in economics and applied to study a variety of problems that include fertility and child mortality (Wolpin, 1984), occupational choice (Miller, 1984), patent renewal (Pakes, 1986), and machine replacement (Rust, 1987). In dynamic discrete choice structural models, agents are forward looking and maximize expected inter-temporal payoffs; the consumers get to know the rapidly evolving nature of product attributes within a given period of time and different products are supposed to be available on the market. The timing of consumers' purchases is usually formalized as an optimal stopping problem where the agent (consumer) must decide on the optimal time of purchase (Rust, 1987). To the authors' knowledge, this is the first attempt to incorporate dynamics in individual choices to revenue management modeling and in particular to formalize tickets' exchange and cancellation decisions for railway intercity trips. The railway operator in consideration offers fully refundable fare and provides flexibility in ticket exchange which makes ticket cancellation and exchange decision to be very crucial to the RM system. Passengers are incentivized to purchase ticket early and adjust their ticket later when they are more certain about trip schedules. The model proposed accounts for passengers' trip adjustment choice and explicitly specifies the probability of exchanging ticket as a function of the set of available exchange tickets. The choice set is constituted by all departure times offered by the railway operator between a specific origin destination pair.

The remainder of the paper is organized as follows. Studies on strategic models for customer purchasing behavior and specifically for ticket cancellation and exchange are reported in Section 2. In Section 3, we formulate a dynamic discrete choice model and we formalize the algorithm used for the dynamic programming problem under study. Data used for model estimation is presented in Section 4, together with descriptive statistics concerning ticket cancellation and exchange behavior. In Section 5 we offer some empirical evidence from the application of the proposed model. Finally, conclusions drawn from the empirical analysis and future research directions are outlined in Section 6.

2. Literature review

There is an emerging research effort toward dynamic frameworks that account for inter-temporal variability in choice modeling. Existing research on inter-temporal price variation that considers forward-looking consumers includes Stokey (1979), Landsberger and Meilijson (1985), and Besanko and Winston (1990). These papers are based on the assumptions that customers are present in the market throughout the entire season, and that the seller's inventory is practically unlimited. Customers purchase at most one unit during the season, and they optimally select the timing of their purchases so as to maximize individual surplus. Su (2007) studied a model of strategic customer by identifying four customer classes, different from each other in two dimensions: high versus low valuations and strategic (i.e., patient) versus myopic (impatient) behavior. The price path is assumed to be predefined by the seller, and after the specific pricing policy is announced, strategic consumers can weigh the benefits of waiting for a discount (if any is offered). The paper demonstrates that the joint heterogeneity in valuations and in the degree of patience is crucial in explaining the structure of optimal pricing policies.

Behavior of ticket cancellation and exchange is clearly influenced by demand uncertainty over time. Stokey (1979) showed that offering a single price can be optimal when inter-temporal differentiation is feasible, but assumes that consumers have perfect information on the future evolutions of their valuations. In Png's (1989), consumers face both uncertainty in their valuations as well as uncertainty about the capacity. Gale and Holmes (1992) examined advance purchase discounts where a monopoly firm offers two flights at different times and where consumers are assumed to not know their preferred flight in advance. In this study, advance purchase discounts are used to smooth the demand of the consumers with a low cost of time. Gallego and Phillips (2004) used a similar approach in their work on flexible products. Dana (1998) showed that advance purchase discounts may improve the revenues of price-taking firms when consumer demand is uncertain. In this case, firms in competitive markets can improve profits by offering advance purchase discounts. Shugan and Xie (2000) developed an inter-temporal consumer choice model for advance purchase which distinguishes the act of purchasing and consumption. The model accounts for buyer's valuation of services that depends on buyer states at the time of consumption and assumes the product capacity to be unlimited. In a later paper, Xie and Shugan (2001) extended this analysis of advance selling to the finite-capacity case and introduced a refund option. Ringbom and Shy (2004) proposed a model where consumers have the same deterministic valuation (maximum willingness to pay) for a certain service of product but different probabilities of showing up; capacity is assumed to be infinite and prices are endogenously given; results show that by adjusting partial refunds it is possible to endogenize the participation rates. Aviv and Pazgal (2008) considered an optimal pricing problem of a fashion-like seasonal good in the presence of strategic customers (forward-looking characteristics) with a time-varying valuation pattern. Customers have partial information about the availability of the inventory and their arrival is assumed to be time dependent. The system is characterized by a leader follower game under Nash equilibrium where customers select the timing of their purchase so as to maximize individual surplus while the seller maximizes expected revenue. Gallego and Sahin (2010) developed a model of customer purchase decision with evolution of trip schedule valuations over time. This analysis considers partial refundable fare based on a call option approach; each customer updates his/her valuation over time and decides when to issue and when to exercise options in a multi-period temporal horizon. Very recently, Baucells et al. (2016) have studied the wait-or-buy problem from a behavioral perspective. The core idea of their method is that the wait-or-buy decision reflects a multidimensional trade-off between the delay in getting an item, the likelihood of getting it, and the magnitude of the price discount. Although their formulation is different from ours, the wait-or-buy problem has similarities with the exchange-cancellation problem proposed in this paper in the context of revenue management.

Meanwhile, a number of studies on demand uncertainty have focused on the supply chain management approach. To our knowledge, in operations management literature, Spinler et al. (2002, 2003) are among the first who incorporated consumer's