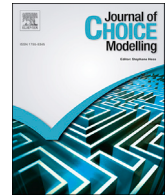


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A choice model for mixed decision variables

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ABSTRACT

Consumers increasingly face decisions among discrete and continuous choice alternatives. Deciding what to wear, watch, read and drive often includes alternatives that allow access for a period of time, as opposed to outright ownership of a good. Consumers may also want both, where access provides a wider variety of offerings than possible with ownership, and ownership provides greater assurance of availability. We propose a mixed discrete/continuous utility model for assessing the economic relationship between mixed decision variables. In application to two studies involving on-line music and videos, we find that commonly used models of choice mischaracterize the economic relationship between access and ownership. We explore the degree to which profit maximizing prices are dependent on correctly assessing whether access through subscription services are substitutes or complements to product ownership.

1. Introduction

Mixed decision variables arise when consumers choose from among discrete and continuous alternatives. Songs, for example, can be accessed with streaming services such as Spotify, and also downloaded from iTunes and GooglePlay. Movies can be watched using services like Netflix and Hulu, or they can be temporarily purchased (i.e., rented) on DVD's obtained by companies like Redbox. Clothing services such as Gwynnie Bee¹ and Golden Tote² allow subscribers to rent clothes instead of purchasing them outright, and Vacation Clubs³ offer access to a variety of vacation destinations as an alternative to making separate room reservations. Subscription services provide an alternative to outright ownership in categories ranging from T-shirts and fly-fishing equipment, to coffee and pet food,⁴ and consumers are increasingly asked to choose between having access (discrete) versus ownership (continuous) in many product categories. For example, the number of people estimated to streamline music in the United States is estimated to be more than 100 million.⁵

In this paper we develop a choice model for a mixture of discrete/continuous quantity decisions to study product access decisions, with the goal of determining whether a subscription service is viewed as a substitute or a complement to ownership. The decision to

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offer access to products via subscription versus ownership is controversial. Some recording artists⁶ have refused offering their music on streaming services because they feel it doesn't adequately compensate writers, producers and artists, and also that streaming services are too experimental. If subscription services and ownership are perceived to be substitute platforms for accessing the product, then it might make sense for an artist or provider to offer just one channel. If viewed as complements, then it would make more sense to offer access through both channels. Google and Apple, for example, give customers the option to choose between streaming or downloading and the New York Times allows digital access to traditional subscribers for a fee, while Netflix requires customers to purchase its streaming and DVD services separately. If the access platforms are complements, firms can more effectively cross-sell consumers who use just one of the services by bundling its offerings. If they are substitutes, then firms need to develop separate promotional strategies for each.

A challenge in modeling mixed decision variables is relating the observed data to the model likelihood. Mixed decision variables do not lend themselves to a search for the choice with maximum utility, as in a discrete choice model, nor to the use of Kuhn-Tucker (i.e., first-order) conditions found in models of multiple discreteness for continuous data. We develop a hybrid estimator that employs a combination of search and first-order conditions to estimate the model. We find in application to two datasets that the inferred relationship between the choice alternatives is affected by the explicit modeling of the budget constraint.

The remainder of the paper is organized as follows: Our model is developed in Section 2 of the paper, and includes a subsection on model estimation. Section 3 describes our empirical application in two conjoint experiments for music and video demand. We find support for our proposed model across both datasets, and find evidence in favor of a complementary relationship between subscription and downloading. We also investigate the use of a traditional discrete choice model for bundled goods, and show that biased parameter estimates and opposite conclusions (i.e., a substitute relationship) result when the continuous purchase decision is not explicitly modeled. Section 4 examines the implications of the model for cross-selling and pricing. Concluding remarks are offered in Section 5.

2. Model development

We develop our model for mixed decision variables using a direct utility model. The advantage of the direct utility model is that it easily lends itself to data with zero demand (i.e., corner solutions) (Chandukala et al., 2007). Direct utility models have been applied to demand for substitute (Kim et al., 2002; Bhat, 2005), and complementary (Lee et al., 2013) goods, models with multiple constraints (Satomura et al., 2011) and models with indivisible demand restrictions (Lee and Allenby, 2014). The challenge in modeling mixed decision variables is in relating the observed variables to an assumed model of utility maximization.

Previous research has not employed direct utility models for assessing rent versus buy decisions, and has instead relied on models of discrete choice (Rao, 2015; Knox and Eliashberg, 2009; Luan and Sudhir, 2006). Research investigating multi-format products (e.g., streaming vs. downloading) has had mixed results in determining whether goods offered with different formats are complements or substitutes. Venkatesh and Chatterjee (2006) examine multi-form magazine content and find that on-line and print versions are complements. Kannan et al. (2009) employs reservation prices to study demand for content delivered in different form (e.g., print, PDF, and the bundle) and find that the offerings are imperfect substitutes. Koukova et al. (2012) find that various usage situations motivate consumers to regard differently formatted digital products as complements to each other. Our investigation accounts for the quantity nature of ownership decisions for music and movie video downloads, and does not a priori assume that renting and buying are substitutes, an assumption often made implicitly when using a discrete choice model.

2.1. Constrained utility maximization

We first consider the context of a consumer deciding between two goods whose benefits are related. Extensions for more than two goods is discussed in a subsequent subsection. One good is offered in the form of a discrete choice while the other good is provided in the form of continuous quantity that he/she needs to determine how many units to buy. We assume the decision maker engages in constrained utility maximization. A budget constraint reflects a limited budgetary allotment in a given purchase occasion. Non-negativity constraints imply that purchase quantities are always equal to or greater than zero. In addition, we take it into account the discrete and continuous decision spaces as constraints on utility maximization. We assume a binary outcome for the access (x_1) and a continuous outcome for the ownership (x_2) decisions:

$$\begin{aligned} \max_{x_{1t}, x_{2t}, z_t} \quad & u(x_{1t}, x_{2t}, z_t) \\ \text{s.t.} \quad & p_{1t}x_{1t} + p_{2t}x_{2t} + z_t \leq E \\ & x_{1t}, x_{2t}, z_t \geq 0 \\ & x_{1t} \in \{0, 1\} \end{aligned} \tag{1}$$

where x_{it} and p_{it} denote the purchase quantity and the unit price of good i at time t , respectively. E represents the total budgetary allotment, and an outside good, z_t , is introduced to account for consumers deciding to save their money and not spend all of it in the category.

We employ a flexible joint utility function that allows for various types of relationship between the two goods (e.g., complementarity, independence, and substitutability).

⁶ <http://www.rollingstone.com/music/news/taylor-swift-shuns-grand-experiment-of-streaming-music-20141106>.

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