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Estimating time-varying parameters in brand choice models: A semiparametric approach

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ABSTRACT

Nowadays, brand choice models are standard tools in quantitative marketing. In most applications, parameters representing brand intercepts and covariate effects are assumed to be constant over time. However, marketing theories, as well as the experience of marketing practitioners, suggest the existence of trends or short-term variations in particular parameters. Hence, having constant parameters over time is a highly restrictive assumption, which is not necessarily justified in a marketing context and may lead to biased inferences and misleading managerial insights.

In this paper, we develop flexible, heterogeneous multinomial logit models based on penalized splines to estimate time-varying parameters. The estimation procedure is fully data-driven, determining the flexible function estimates and the corresponding degree of smoothness in a unified approach. The model flexibly accounts for parameter dynamics without any prior knowledge needed by the analyst or decision maker. Thus, we position our approach as an exploratory tool that can uncover interesting and managerially relevant parameter paths from the data without imposing assumptions on their shape and smoothness.

Our approach further allows for heterogeneity in all parameters by additively decomposing parameter variation into time variation (at the population level) and cross-sectional heterogeneity (at the individual household level). It comprises models without time-varying parameters or heterogeneity, as well as random walk parameter evolutions used in recent state space models, as special cases. The results of our extensive model comparison suggest that models considering parameter dynamics and household heterogeneity outperform less complex models regarding fit and predictive validity. Although models with random walk dynamics for brand intercepts and covariate effects perform well, the proposed semiparametric approach still provides a higher predictive validity for two of the three data sets analyzed.

For joint estimation of all regression coefficients and hyperparameters, we employ the publicly available software BayesX, making the proposed approach directly applicable.

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1. Introduction

The marketing literature comprises a large number of applications of discrete choice models directed at explaining consumer brand choices (see Russell, 2014, for a recent overview). Within the class of discrete choice models, the multinomial logit (MNL) model has been applied so regularly that it is called the "workhorse model" of marketing today (Rossi, Allenby, & McCulloch, 2005, p. 35).

The MNL model is frequently applied to data from consumer or household[1] scanner panels collected during observation periods reaching from six months to several years (Bronnenberg, Kruger, & Mela, 2008). The deterministic utility function of the MNL model captures the influence of variables, which are supposed to be the drivers of consumers' brand choice behavior. In the context of panel data, a consumer's utility of buying a certain brand is typically assumed to depend on brands' actual prices and related reference price terms, promotional activities (e.g., displays and feature advertising), current brand loyalties, and alternative-specific intercepts representing intrinsic brand utilities (Guadagni & Little, 1983). In addition, consumer heterogeneity plays a major role in marketing (Allenby & Rossi, 1999), and hence nowadays, almost all versions of the MNL model also account for unobserved heterogeneity, leading to the so-called mixed logit (MXL) model (Train, 2009).

In the majority of publications, estimated parameters reflecting the influence of those predictors on brand choice as well as estimated brand intercepts have been assumed to be constant over time, i.e., equal across all purchase occasions. However, marketing literature as well as experiences reported by marketing practitioners suggests the possibility of changing consumer choice behavior over time.

The effects of marketing variables might change because of many different reasons. During an economic downturn, e.g., price sensitivity may increase (Gordon, Goldfarb, & Li, 2013) and consumers may increasingly search for price deals advertised by features and displays. Price sensitivity may also vary depending on the intensity of and time since previous promotional activities in the product category (e.g., Foekens, Leeflang, & Wittink, 1999; Kopalle, Mela, & Marsh, 1999). Moreover, an advertising campaign may improve a brand's awareness and image or its perceived quality over time with the result of a higher intrinsic brand utility. Advertising may as well decrease price sensitivity (e.g., Boulding, Lee, & Staelin, 1994; Kaul & Wittink, 1995). Importantly, advertising activities are typically not recorded in panel data.

The brand intercepts of a model, often referred to as brand preferences, represent the intrinsic utility of a brand net of (possibly changing) marketing mix effects and can also be interpreted as the utility-based brand value (Kamakura & Russell, 1993). Brand intercepts might also evolve over time, because consumers' brand choice may be affected by situational factors associated with the personal consultation with salespeople, out-of-stock situations, or different usage situations (Miller & Ginter, 1979; Srivastava, Shocker, & Day, 1978). Furthermore, marketing practitioners report an increase in the demand for higher-tier brands in certain product categories (e.g., coffee, chocolate) in the run-up to special events like Christmas, Easter, or Mother's day. In contrast to potential long-term trends in consumer choice behavior due to, e.g., advertising campaigns, situational factors will probably result in short-term fluctuations of parameters.[2]

In all these cases, a more flexible model specification allowing for time-varying brand intercepts and time-varying effects of covariates is presumed to provide a better explanation and prediction of consumer choice behavior as compared to a model with constant parameters only. We will explore this potential improvement especially regarding prediction accuracy in holdout samples in our empirical application. That way, we are able to validate whether changes in consumer behavior across time are inherent in our data at hand.

From a managerial point of view, an unexpected short-term increase in demand for a specific brand can cause an out-of-stock situation resulting in decreased profits and dissatisfied customers. An unexpected decrease in demand, on the other hand, may lead to increased inventories or deterioration of goods and, therefore, to higher costs. For this reason, it is essential to know whether and when consumers may vary in their sensitivity to price and promotional activities or in their brand preferences even if the reasons/causes for the observed variations are not fully understood. Managers can also learn which recurring events (e.g., festive occasions) are actually important and how they influence demand (e.g., via changes in intrinsic brand utilities or changes in marketing-mix sensitivities). This information can then be potentially used for future marketing strategies (e.g., exploiting peak-demand). Ignoring time-varying effects concerning brand loyalties or consumer response to promotional activities may further mask (potentially harmful) trends in a product category like decreasing loyalties or increased bargain hunting. Further, changes in intrinsic brand utilities can be an indication of changes in the competitive structure between brands. For example, if the perceived quality of an established brand increases over time (e.g., via advertising investments), it may become a competitor for the higher-tier brands in the category. While our approach does not explicitly address the supply side, time-varying effects of marketing-mix variables also imply changes in optimal marketing policies over time.

The model proposed in this paper can support managers in uncovering time-varying parameters and may serve as a basis to improve related marketing decisions. To be precise, we do not claim to present a model that incorporates all effects that can cause dynamics explicitly because the list of potential candidate variables is long and apparently depends on the context of the specific research question, the industry and/or product category, and/or the characteristics of the data set. We instead recommend

[1] In the following, we will use the terms consumer and household interchangeably.

[2] We use the terms short- and long-term to conceptually differentiate between effects on the weekly or bi-weekly level and ones on a longer time-scale (e.g., half a year or longer). This definition is fairly arbitrary and is used to simplify verbal interpretations. It is, however, not related to the definition used in persistence modeling (see, e.g., Dekimpe & Hanssens, 2004 for an overview).

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