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A Nonparametric Approach to Identifying Latent Relationships in Hierarchical Models

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Abstract

This paper provides a method for nonparametrically modeling the relationship between consumer preference for product features, such as reliability or durability, and covariates that describe consumers and how they use the product. This relationship is of interest to firms designing and delivering products to a market because the extent to which consumers are sensitive to particular features determines the potential profitability of product offerings, and affects decisions relating to appropriate distribution outlets and advertising strategies. The successful identification of these relationships also aids in efficiently targeting marketing activities to specific segments of the consumer population.

The relationship between consumer preference for product features and observable covariates is important but is typically unknown. In addition, these relationships are often deeply embedded in a model hierarchy and are not observed directly. For example, in models of household choice, the observed outcomes are multinomial with probabilities driven by latent utilities or values that consumers place on the choice alternatives. These utilities are in turn a function of characteristics, such as price and product features, which are differentially valued. Of primary interest is the relationship between consumer sensitivity to product characteristics and readily observed covariates such as household demographics or aspects of product usage. Because the relationships of interest are not directly observed, it is difficult to draw inferences about them without formal statistical models.

This paper presents a three-level hierarchical Bayes model for modeling binary consumer preferences as a function of observable covariates. The hierarchical model nonparametrically estimates the relationships between consumer preferences for product features and the covariates without assuming a specific functional form. A nonparametric model is particularly useful in the exploratory analysis of consumer data in which the primary purpose of the analysis is to generate further questions rather than provide specific answers to well-posed questions. This type of analysis is frequently encountered in marketing where a series of studies are commissioned to better understand the nature of demand. The first level of the hierarchy in the Bayesian model relates the binary consumer choice to the sensitivities of the consumer to product attributes such as brand name, price, reliability, and durability. The second level of the hierarchy models the heterogeneity across consumers using functions that relate attribute sensitivities to observable covariates. This level of the hierarchy also allows each respondent to have unique demand coefficients by introducing random effect components. The third level of the hierarchy specifies a smoothness prior for each of the unknown functions used in the second level. The approach is flexible and works well both when the unknown function can be closely approximated by a linear function and when it cannot be. A Bayesian model selection technique is used to determine which functions can be modeled using a linear function and which ones should be modeled nonparametrically to provide the necessary flexibility to estimate the function accurately.

The proposed methodology is illustrated using data from a survey of consumer preferences for features of marine outboard engines that was collected as part of a consulting project. Our analysis focuses on measuring consumer preferences for engine features and their relationships to two variables related to boat length and engine size. Consumer preferences for engine features were obtained through a national survey conducted over the telephone. Preferences were elicited by means of a pairwise evaluation in which respondents chose between two engines that were identical in every respect except for two engine features. The methodology can be modified to allow for more complex comparisons such as conjoint data collected in full profiles.

The application of a Bayesian model selection procedure indicates that 4 of the 28 covariate relationships in the model are nonlinear, while the other 24 are linear. The preferences associated with these four functions are involved in 56% of the pairwise comparisons in the study. Therefore, in practice, if the nonlinear functions are not properly estimated there is the potential to draw misleading inferences regarding 56% of the pairwise choices. Firms can use the estimates of the functions relating preferences to covariates in a number of ways. First, they can use the covariates to determine the total number of consumers who have high demand for a particular product feature, and then they can target communication efforts to those individuals. Alternatively, the empirical results can be used as a basis of subsequent analysis to obtain a more complete characterization of a market segment.

(*Consumer Preferences*; *Cubic Smoothing Spline*; *Hierarchical Bayes Model*; *Markov Chain Monte Carlo*; *Randan Effects*)

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