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A multinomial probit conjoint simulator

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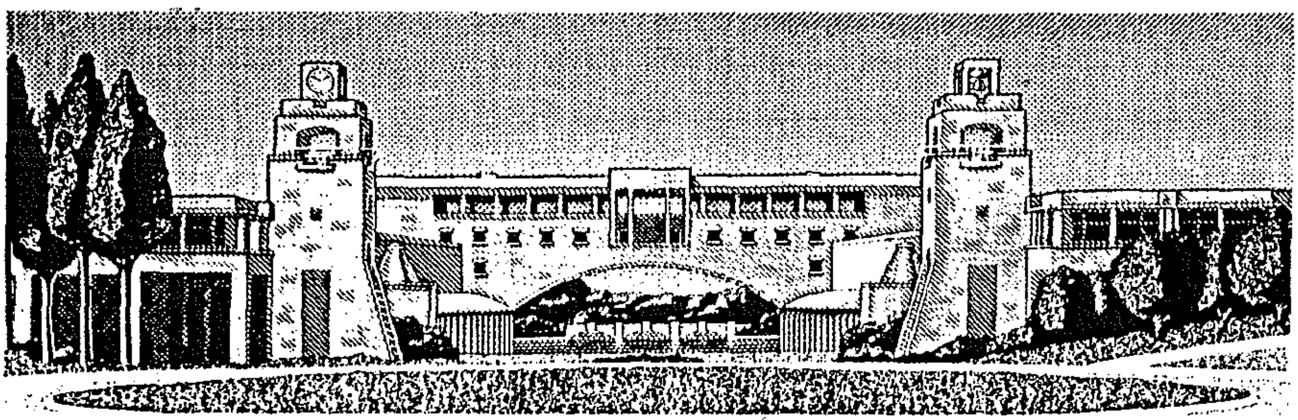

B O N D U N I V E R S I T Y

A MULTINOMIAL PROBIT CONJOINT SIMULATOR

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ABSTRACT

Probabilistic conjoint choice simulators based on Luce's choice axiom (BTL or Multinomial Logit simulators) suffer from the Independence from Irrelevant Alternatives (IIA) property. This is not very realistic in many real situations where some products are more similar to one of the alternatives than to others. A Multinomial Probit (MNP) choice simulator is proposed which allows for correlated alternatives to exist in a simulated market. The MNP simulator is illustrated with an empirical example and contrasted with results from a logit simulator.

A MULTINOMIAL PROBIT CONJOINT SIMULATOR

INTRODUCTION

Over the past two decades the use of conjoint analysis in marketing research has become so widespread that it can come close to claiming a place of equal stature with other multivariate techniques such as discriminant analysis, factor analysis, cluster analysis and multiple regression in the researcher's bag of statistical tools. The part worths which can be estimated for each respondent in a conjoint study essentially serve two purposes. The first of these relies on a direct examination of the part worths. One procedure is to undertake a comparison of the distributions of part worths across the various product attributes in order to identify which of the attributes are more (or less) important in driving buyer preferences. These part worths can also be used as input for cluster analysis in order to identify segments of individual buyers who have similar preferences with respect to the product under investigation. In either of these cases, the focus is on the distribution of the part worths (across attributes or individuals).

The second major use of the estimated conjoint part worths are "as grist for the simulator mill" (Green and Krieger 1988, p. 114). In other words, the part worths are used to produce estimated utilities or valuations for a set of product concepts defined in terms of the product attributes used in the conjoint study. These utilities are then used in some way to calculate the share of choice of each of the product concepts. Although many rules can be used to produce these choice shares, by far the most popular are the simple share of first choice rule whereby the buyer is assumed to purchase the alternative product concept with the highest predicted utility, and the probabilistic choice rules based on variations of Luce's (1959) choice axiom. In turn, the most popular of these latter models are the so-called Bradley-Terry-Luce (BTL) model (Bradley and Terry 1952, Luce 1959) and the logit model (McFadden 1973, Gensch and Recker 1979).

Huber and Moore (1979) and Green and Krieger (1988) have compared these three choice simulator rules with very interesting results. However, both of the probabilistic choice models possess a property known as "Independence from Irrelevant Alternatives" (IIA). This leads to the nonintuitive result that if a new alternative product concept is introduced into the simulated market choice environment which is very similar to one or more of the previously defined products while also being not very similar to others, the choice simulator will estimate a share for this new alternative which is made up of components that are proportional to the original shares of all the alternatives. A more realistic situation would be that this new alternative should take a larger than proportional share away from those previously defined products with which it is most similar and take a very small proportional share away from those alternatives with which it is very dissimilar. Indeed, this is exactly the way most markets of interest to marketing researchers actually are observed to operate. Hence, a conjoint choice simulator which exhibits this property would seem to be preferable to one that is subject to IIA.

One choice model not subject to IIA which may be used in just such a choice simulator is the multinomial probit (MNP) model (Hausman and Wise 1978, Daganzo 1979, Currim 1982). The purpose of the present paper is to describe the use of MNP as a choice simulator in conjoint studies. In the remainder of this paper we detail a suggested approach to the use of MNP in conjoint choice simulators and provide an empirical example of its use in a conjoint study of the market for loanable funds. We compare the results of using our MNP choice simulator with results using the usual logit choice simulator and find the MNP results much more intuitively appealing in the empirical study at hand. The paper concludes with suggestions for future work on MNP choice simulators.

CONJOINT SIMULATORS

The basic idea behind conjoint choice simulators can be thought of as consisting of three steps. First, a conjoint study is carried out and part worths for each sampled individual are calculated. Second, for a specific configuration of the marketplace in term of product offerings defined by combinations of attributes used in the conjoint experiment, valuations of each product are calculated for each sampled individual using the estimated part worths. For example, assuming a market with six products, valuations of each of these six for each individual would be calculated by combining the relevant part worths. Let us call these valuations Vi where i refers to the product.

The third step involves the use of the estimated V_i within some choice rule to either predict which alternative product would be chosen by each individual in the sample or the probabilities of each individual choosing each alternative product. The former is usually implemented using the maximum utility rule where it is assumed that the alternative with the largest V_i would be chosen. Market shares (or shares of choice) are then determined by calculating the proportion of individuals for which each alternative product is the one with the maximum calculated utility or valuation.

On the other hand, probabilistic rules require the calculation of a vector of probabilities for each individual using the V_i and then either using the highest probability as an indicator of which alternative would be chosen or by directly aggregating the probabilities to get a predicted market share. By far the most popular probabilistic rules are the BTL rule where the market share of alternative i (MS_i) is calculated by

$$MS_i V_i / \sum_{j=1}^{J} V_j \quad (1)$$

and the multinomial logit (MNL) choice rule where

$$MS_i = \exp(V_i) / \sum_{j=1}^{J} \exp(V_j) \quad (2)$$

The problem with each of these rules is that they are subject to the independence from irrelevant alternatives property. Hence, using either of these rules as a choice or market share simulator in many marketing situations will not be very realistic.

A MULTINOMIAL PROBIT SIMULATOR

A choice model that is not always subject to the IIA property is the multinomial probit (MNP) model (Hausman and Wise 1978, Daganzo 1979, Currim 1982). However, when there are more than two alternatives in the choice set (market), calculating probabilities with the MNP model is quite difficult since multiple integrals must be evaluated (usually numerically). Nonetheless, it is possible to use numerical sampling procedures (i.e Monte Carlo methods) to produce probabilities in a choice simulator which will not be subject to IIA. The steps in our suggested procedure are as follows.

The key to the MNP simulator lies in the estimation of a covariance matrix for the alternatives in the simulated market environment. The MNL and BTL models both assume that this covariance matrix is diagonal (i.e. all off-diagonal covariance terms are zero). It is these zero covariances that give rise to the IIA property of these models. The MNP model allows non-zero covariances and hence violation of IIA. The problem then is to find a reasonable estimator for the covariance matrix.

One solution is to use the simulated choice set (market) design points. If we treat the vector of attributes for each alternative in the choice set as a vector in n-space (assuming n attributes), the angle between each vector gives an indication of the "closeness" of each alternative to another (i.e. closer should be perceived similarly by the respondent). We can then use the cosine of the angle between each vector as the entries in our correlation matrix. Denoting the angle as Θ, we can write this more formally as

$$\cos(\Theta) = a'b \,/\, \|a\| \, \|b\| \quad (3)$$

where a and b are vectors of design points. To convert these correlations into a covariance matrix, we multiply each element by an error variance. This can be estimated for each respondent if the conjoint task required ratings of designed alternatives and, hence, part worth estimation by ordinary least squares (OLS). Let the resulting covariance matrix be designated Ω.

Now for each individual we generate normal random variables with mean $V=(V_1,V_2,\ldots,V_n)$ and covariance matrix Ω and note at each iteration the largest generated value. Assume this is the chosen alternative. This process is repeated for each individual until some convergence criteria is satisfied or a predetermined number of iterations are completed. This results in a vector p for each individual which is a count of the number of times each alternative was chosen (in a simulated sense). Dividing the elements of this vector by the number of iterations provides an estimate of individual choice probabilities. Aggregating these across the sample yields an estimate of market shares. Since the generated probabilities allow for correlation across alternatives, these simulated shares should not be subject to the IIA property. We now turn to an empirical example to illustrate this point.

AN EMPIRICAL EXAMPLE

As part of a larger study of the retail funds market in Australia conducted in the early 1980's, 961 individuals identified as "potential investors" were interviewed. Each respondent provided ratings on a 9-point likelihood to invest scale for 32 investment packages defined in terms of six attributes. These attributes and their levels were:

Term (length to maturity)	1,3,5 or 7 years
Interest Rate	10,12,14 or 16%
When Interest Paid	Monthly, Quarterly, Semi-Annual, Deferred
Interest Rate Type	Fixed, Variable
Security	Totally Secure, Reasonably Secure
Liquidity	Liquid, Not Liquid

The design used allowed the estimation of all main effects and selected interactions using OLS. The results presented here refer only to those 584 respondents who provided a rating of 5 or more on a ten point scale to a question about their willingness to invest in a large finance company (the client for the study).

In order to illustrate our MNP approach to share simulation it is necessary to specify some reasonable choice alternatives in terms of the six attributes listed above. Consider the four investment instruments listed in Table 1.

TABLE 1

CHOICE SIMULATOR ALTERNATIVES

Alternatives	A	B	C	D
Interest Rate(%)	14.5	14.25	14.5	14.75
Term(Yrs)	3	3	3	3
When Paid	Q	M	Def	Def

(Note: Liquidity, Security, Interest Type set at same level for all four example packages)

Applying both a standard MNL and our proposed MNP choice simulator to the above alternatives yielded the results listed in Table 2.

TABLE 2

SIMULATED SHARES

Market Share with MNP (MNL) Simulator

Alternative	Set 1	Set2	Set 3
A	42.5(44.9)	23.8(29.2)	21.8(22.7)
B	57.5(55.1)	52.3(44.2)	51.0(38.2)
C		23.9(26.6)	8.9(18.9)
D			18.3(20.2)

First, assume that the market consists of two products labelled A and B. Using either the MNP or MNL simulator leads to the conclusion the B is preferred to A by either 15 (MNP) or 10.2 (MNL) share points. Now suppose that alternative C is added to the market. This product is identical to A except that it defers interest until maturity (a tax advantage) instead of paying interest quarterly. C differs from B in that it pays a higher interest rate but B pays interest monthly (a popular feature across most of the sample). Hence, intuitively we would expect that the share of the market obtained by C would come more at the expense of A that B. We observe this in the case of both simulators but the result is far more pronounced in the MNP case. Since IIA holds at the individual level but we are aggregating the simulation results from 584 individuals, the MNL simulator does not exhibit the IIA property exactly. This occurs because the MNL model is nonlinear. Nonetheless, the MNP results here are the more sensible in our view.

This is illustrated more vividly in Set 3 where alternative D is added to the market. D is identical to C except that it pays a slightly higher interest rate. Since we are working with probabilistic models, alternative C will still capture some market share in a simulation. However, we would expect this share to be rather small. This is exactly what happens with our MNP simulator but the MNL simulator predicts a market share for C which is over twice the level of the MNP simulator when alternative D is present in the choice set.

FURTHER RESEARCH

The results presented above represent only a simple illustration of the differences which may be obtained with a conjoint simulator based on the multinomial probit model not subject to IIA when compared to the more usual multinomial logit simulator. An obvious next step in research on this topic would be a careful Monte Carlo experiment designed to examine the degree of accuracy of the MNP simulator compared to other simulators when the true degree of IIA violation and resulting market shares is known.

In addition, further work can be undertaken with respect to the way the covariance matrix is specified for use in the MNP simulator (see equation 3). Our method seems to work but only if the original conjoint experiment required profile ratings. Since many applications of conjoint are conducted using rankings, a way to estimate an individual error variance would prove useful.

Finally, a fruitful line of research would be an examination of the effectiveness of various stopping rules for use in our MNP simulator. We essentially stopped the simulation process for any individual when the change in the predicted vector of probabilities was less than an arbitrarily small vector. Again, this seemed to work in our experiments but there are other stopping rules which may be more efficient.

REFERENCES

Bradley, R.A. and M.E. Terry (1952), "Risk Analysis of Incomplete Block Designs: I. The Method of Paired Comparisons," Biometrika, 39, 324-345.

Currim, Imran S. (1982), "Predictive Testing of Consumer Choice Models Not Subject to Independence of Irrelevant Alternatives," Journal of Marketing Research, 18 (May), 208-22.

Daganzo, Carlos (1979), Multinomial Probit: The Theory and its Application to Demand Forecasting, New York: Academic Press.

Gensch, Dennis H. and Wilfred W. Recker (1979), "The Multinomial, Multiattribute Logit Choice Model," Journal of Marketing Research, 16 (February), 124-132.

Green, Paul E. and Abba M. Krieger (1988), "Choice Rules and Sensitivity Analysis in Conjoint Simulators," Journal of the Academy of Marketing Science, 16 (Spring), 114-127.

Hausman, Jerry A. and David A. Wise (1978), "A Conditional Probit Model for Qualitative Choice: Discrete Decisions Recognizing Interdependence and Heterogeneous Preferences," Econometrica, 48 (March), 403-426.

Huber, Joel and William Moore (1979), "A Comparison of Alternative Ways to Aggregate Individual Conjoint Analyses," in Proceedings of the AMA Educators' Conference, Chicago: American Marketing Asociation, 64-68.

Luce, R. Duncan (1959), Individual Choice Behaviour. New York: John Wiley & Sons.

McFadden, Daniel (1973), "Conditional Logit Analysis of Qualitative Choice Behavior," in Frontiers in Econometrics, P. Zarembka, ed., New York: Academic Press, 105-142.