"A RATIONAL RANDOM BEHAVIOR MODEL OF CHOICE"

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Abstract

In this paper, a Multinomial-Dirichlet-Geometric model of consumer brand choice is developed. This individual-level stochastic choice model is derived as an extension of Theil's theory of rational random behavior. These behavioral assumptions permit modeling of changes in likelihood of purchase as consumers are confronted with environmental factors whose occurrence and exact nature could not be anticipated at the planning stage of a shopping trip. Moreover, the model allows for uncertainties about future events which might impact actual choice to be built into the choice process alongside a traditional choice model which reflects preferences and/or utilities (and potential uncertainties surrounding them). Empirical results using consumer diary purchase panel data indicate a strong superiority of the model developed compared with previous models which assume stationary preference vectors.

Key Words: MULTINOMIAL; DIRICHLET; GEOMETRIC; RATIONAL RANDOM BEHAVIOR; STOCHASTIC BRAND CHOICE; CONSUMER PURCHASE DATA

1. INTRODUCTION

An important problem in applied economics is modeling the choice process of decision makers. A significant portion of this literature views choice as a stationary stochastic process where an economic agent is assumed to have a vector of probabilities of choosing each option.

Many of these models have been developed in the marketing science literature where the economic agents are consumers and the options are brands. However, these models generally do not model choice behavior as a process since they merely model the evaluation at the point of the actual choice decision and provide a statistical description of that evaluation. With the exception of Fornell et al. (1985), the models do not capture the process which develops over time and which is an inherent characteristic of brand choice. For example, many shoppers develop a list of items to be purchased before they go to the supermarket. During the shopping trip they might, however, deviate from that list and purchase brands (and items) not mentioned on the list. Hence, their initial choice expressed on the shopping list does not necessarily match the items with which they leave the store.

This sequence of events and the apparent changes in revealed preferences over time (i.e., non-stationarity) has received little attention in the stochastic choice modeling literature thus far. However, Theil (1974, 1975a,b) has developed a theory of rational random behavior which is explicit about the behavioral underpinnings of the choice process and, under certain assumptions about the nature of the decision maker's utility function, results in a closed-form solution for the optimal decision distribution.

The purpose of this paper is to extend Theil's model to a stochastic consumer brand choice model. While the model produced resembles those already existing in the literature (see, for example, Massy, Montgomery, and Morrison 1970, Bass 1974, Bass, Jeuland, and Wright 1976, Zufryden 1977, Sabavala and Morrison 1981), there are several important differences. First, the inherent stochasticity of the choice process is shown to be a direct result of the underlying assumed behavioral process rather than asserted *a priori*. Second, the model is developed from an economic theory of rational random behavior. As a consequence, the parameters have an economic interpretation. Finally, the model is a generalization of several well-known models in that it is specified at the household level (complete heterogeneity) and the choice vector can change over time although the **underlying** distribution is assumed to be stationary. Using consumer diary panel data, we estimate model parameters at the family level, with the estimated family parameters linked to household descriptor variables.

2. MULTINOMIAL-DIRICHLET-GEOMETRIC (MDG) CHOICE MODEL

Derivation of Individual-Level Choice Model

The assumptions underlying the individual-level choice model are: (a) that choices on different purchase occasions are made independently from one another (i.e. the Multinomial assumption), (b) that the probability vector describing the choice of an individual on a single purchase occasion is a random draw from an optimal decision disribution (i.e., the Dirichlet assumption, as derived hereafter), and (c) that choices made on different purchase occasions can be governed by different choice vectors drawn from the same optimal decision distribution. This change in choice vectors is incorporated through a discrete time renewal process (i.e. the Geometric assumption). Hence, the statistical description of the choice outcome is very similar to the one obtained from stochastic brand choice models. The basic difference between those models and the one developed here is that in the traditional stochastic brand choice models, the distribution of the choice vector describes consumer heterogeneity (Jones, 1973; Bass, Jeuland, and Wright, 1976; Jeuland, Bass, and Wright, 1980). In other words, revealed preferences are fixed at the individual consumer level. The individual specific model developed here assumes that they are stochastic and characterized by an optimal decision distribution derived within the framework of the economic theory of rational random behavior (Theil 1974, 1975a,b). Moreover, while assumption (c) is added for completeness, assumptions (a) and (b) follow directly from economic theory as opposed to being directly assumed *ex ante*.

The Multinomial assumption is the multivariate extension of the traditional Bernoulli (i.e., two-state zero-order; Massy, Montgomery and Morrison 1970, p. 51) process underlying the zero-order brand choice models (Bass, Jeuland, and Wright, 1976; Bass et al., 1984). In the individual choice framework developed here, the probability vector describing choice is drawn from a density $g(\theta)$. Density $g(\theta)$ is a Dirichlet density (Johnson and Kotz 1972, p.231) derived as the optimal decision distribution within Theil's economic theory of rational random behavior.

The theory of rational random behavior views choice as a two-stage process: a planning stage and an implementation stage. At the planning stage, an individual considers and evaluates major factors and uncertain future events which could affect choice at the implementation stage. In a brand choice framework, the major factors include product characteristics and benefits, buying habits, past preferences, etc. These factors are evaluated in the traditional way common to many choice models and provide the theoretically optimal decision (identified by a choice rule and a preference or utility function; see Corstjens and Gautschi 1983). Future events such as in-store promotions, sales, point-of-purchase variety-seeking, etc., are incorporated as random events. Incorporating them into a choice decision alongside the theoretical optimal decision makes the decision maker behave statistically. Accordingly, at the planning stage, the choice decision is not a preference vector but a density or decision distribution. Moreover, at the planning stage, a consumer's preferences are fundamentally stochastic. The density around the theoretically optimal decision (identified by a choice rule and a preference or utility function) characterizes the consumer's attitude towards uncertain future events which could affect a choice decision when it is finally executed at the implementation stage.

The decision distribution $g(\theta)$ is derived from maximizing the criterion function $\psi = \psi[E(L),H]$. $E(L)$ denotes the expected loss with respect to the preference function $f(\theta)$ associated with a consumer's vector of revealed preferences towards n brands at the planning stage, $\theta = (\theta_1, \theta_2, \ldots, \theta_n)$. Denoting the theoretically optimal vector by μ, the expected loss using a quadratic Taylor expansion can be approximated by

$$E(L) = -\tfrac{1}{2} \, {}_0\!\int^1 {}_0\!\int^1 \cdots {}_0\!\int^1 [(\theta - \mu)'A(\theta - \mu)]g(\theta)d\theta_1 d\theta_2 \ldots d\theta_n. \qquad (1)$$

where A is the symmetric negative definite Hessian matrix of preference function $f(\theta)$ (a Klein-Rubin utility function or $f(\theta) = \sum_{i=1}^{n} \mu_i \ln\theta_i$; Barten 1977, Stone 1954, Theil 1975a) evaluated at μ.

The second component, H, of the criterion function, ψ, is the multivariate entropy measure

$$H = -{}_0\int^1 {}_0\int^1 \cdots {}_0\int^1 g(\theta)\ln g(\theta)d\theta_1 d\theta_2 \ldots d\theta_n. \tag{2}$$

This entropy measure has been used extensively in rational random theory as a measure of dispersion. In sum, the decision maker is assumed to simultaneously minimize the expected loss and maximize the dispersion of the preference vector around the optimal decision. The first assumption is obvious; the latter is derived from the "flexibility" obtained to permit consumers to adjust to the stockout, sale, and variety-seeking factors.

The criterion function ψ to be maximized is monotonic in both E(L) and H. Hence, its maximization is equivalent to maximizing H defined in (2) subject to two constraints. The first one is a normalization constraint. The second constraint states that the expected loss should take on an appropriately specified value L_0, which implies a lower bound on the loss a consumer will sustain. Ignoring the second constraint, the maximization problem is very similar to the formulation of Herniter's entropy model (1974). However, by considering the additional constraint, the inflexibility of Herniter's model in a multiple brand framework noted by Bass (1974) is circumvented.

Based on the calculus-of-variations approach, it can be shown (cf. Theil, 1974) that the optimal decision distribution equals

$$g(\theta) = C\left[\prod_{i=1}^{n-1} \theta_i^{\lambda_2\mu_i}\right] \cdot \left[1 - \sum_{i=1}^{n-1} \theta_i\right]^{\lambda_2\mu_n} \tag{3}$$

where C is a normalizing constant equal to $C = e^{(\lambda_1 - 1)} \prod_{i=1}^{n} \mu_i^{-\lambda_2 \mu_i}$, μ_i are the theoretically optimal decisions, and λ_1 and λ_2 are the multipliers associated with, respectively, the first and the second constraint.

The parameter λ_2 has an interesting interpretation. Since it is the Lagrangian multiplier on the second constraint of the entropy objective function, λ_2 is a measure of a consumer's responsiveness in terms of desired variance in θ from changes in admissible loss. Thus, λ_2 measures the extent to which the consumer's flexibility is enhanced as adherence to optimal purchase probabilities is relaxed.

Since $\sum_{i=1}^{n} \theta_i = 1$, expression (3) is the density of a standard Dirichlet distribution (Mosimann, 1962; Connor and Mosimann, 1964; Rogers and Young, 1973) with parameters $\mu_i \lambda_2 + 1$ for $i = 1, 2, \ldots, n$. Note, furthermore, that the mean vector of the optimal decision distribution $g(\theta)$ is not the theoretically optimal decision vector μ. The μ_i's are, however, the modal values of the marginal Beta densities underlying the standard Dirichlet density shown in (3).

The question that arises is whether an individual consumer draws a probability vector from the density and holds on to it for a period of time, or whether a new vector is drawn each time a purchase is made. Since it is more general to assume the latter, it is hypothesized that at each point in time there is a probability γ that a new vector is drawn from $g(\theta)$. Hence, assuming that the time between changes is geometrically distributed with parameter γ, or

$$p(t/\gamma) = \gamma(1 - \gamma)^{t-1} \tag{4}$$

where t is measured in discrete time periods, the draws are described by a discrete time renewal process similar to the one underlying Howard's Dynamic Inference Model (1965).

Derivation of Likelihood Functions

Assuming a Multinominal process and the optimal decision distribution (3), the probability of observing a sequence of k purchases of which k_i were choices of brand i (i = 1, 2, ..., n) is provided by the Multinomial density

$$L(k_i\ ;\ i = 1,2,\ldots,n/\theta,\ k) = \frac{k!}{\prod_{i=1}^{n} k_i!}\left[\prod_{i=1}^{n-1} \theta_i^{\,k_i}\right]\left[1 - \sum_{i=1}^{n-1} \theta_i\right]^{k - \sum_{i=1}^{n-1} k_i} \qquad (5)$$

The joint density of k_i (i = 1, 2, ..., n) and θ can then be expressed as the product of (3) and (5),or

$$h(k_i;\ i = 1, 2, \ldots, n,\ \theta/k)$$

$$= C\,\frac{k!}{\prod_{i=1}^{n} k_i!}\left[\prod_{i=1}^{n-1} \theta_i^{\,\lambda_2\mu_i + k_i}\right]\left[1 - \sum_{i=1}^{n-1} \theta_i\right]^{\lambda_2\mu_n + k - \sum_{i=1}^{n-1} k_i} \qquad (6)$$

Compounding the Dirichlet density (3) with the Multinomial process provides the marginal density of k_i (i = 1, 2, ..., n), and after integrating θ_i (i = 1, 2, ..., n) out, it can be shown that

$$f(k_i;\ i = 1, 2, \ldots, n/k) = C \frac{k!}{\prod_{i=1}^{n} k_i!} \quad \frac{\prod_{i=1}^{n} \Gamma(\mu_i\lambda_2 + k_i + 1)}{\Gamma(\lambda_2 + k + n)} \tag{7}$$

which is a Multinomial-Dirichlet density with Γ denoting a Gamma function.

Given the joint density shown in (6) and the marginal density derived above in (7), the marginal density of θ given k_i ($i = 1, 2, \ldots, n$) can be obtained, or

$$q(\theta/k_i;\ i = 1, 2, \ldots, n, k) = \frac{h(k_i;\ i = 1, 2, \ldots, n, \theta/k)}{f(k_i;\ i = 1, 2 \ldots, n/k)}$$

and, hence,

$$q(\theta/k_i;\ i = 1, 2, \ldots, n, k)$$

$$= \left[\frac{\Gamma(\lambda_2 + k + n)}{\prod_{i=1}^{n} \Gamma(\mu_i\lambda_2 + k_i + 1)}\right] \left[\prod_{i=1}^{n-1} \theta_i^{\lambda_2\mu_i + k_i}\right] \left[(1 - \sum_{i=1}^{n-1} \theta_i)^{\lambda_2\mu_n + k - \sum_{i=1}^{n-1} k_i}\right]$$

which is a Dirichlet density with parameters $(\lambda_2\mu_i + k_i + 1)$ for $i = 1, 2, \ldots, n$. The probability that brand i will be selected given k_i purchases of brand i were made in k purchases equals

$$p(i/k_i;\ i = 1, 2, \ldots, n, k) = \frac{\lambda_2\mu_i + k_i + 1}{\lambda_2 + k + n}$$

which equals the mean of the marginal Beta density for θ_i. Accordingly, the likelihood of observing a specific sequence of k purchases equals

$$L(k) = \prod_{t=1}^{k} \prod_{i=1}^{n} \left[\frac{\lambda_2 \mu_i + k_{it} + 1}{\lambda_2 + k_t + n} \right]^{\delta_{i,t}} \tag{8}$$

with $\delta_{i,t} = 1$ if brand i was bought at t, and $\delta_{i,t} = 0$ otherwise; k_{it} denotes the number of times i was purchased by time t and k_t denotes the total number of purchases made by time t. Underlying this likelihood function is the assumption that all choices were made with a constant probability vector drawn from the density $g(\theta)$ shown in (3).

If we now assume that the individual consumer can draw a new vector <u>before</u> each purchase occasion, this process can be incorporated as a discrete time renewal process. Assume for example, that the points at which a new vector is drawn are known and are represented by a change vector v. Before the first change, k_0 purchases are made with a fixed probability vector. Hence, the likelihood of those purchases can be expressed as a function similar to the likelihood expressed in (8) above. This can be done for all b_j sequences for $j = 0, 1, \ldots, c$. Given the Multinominal character of the choice process, the likelihood of the entire choice sequence can be expressed as

$$L\ (k) = \prod_{j=0}^{c} \prod_{t=1}^{b_j} \prod_{i=1}^{n} \left[\frac{\lambda_2 \mu_i + k_{ijt} + 1}{\lambda_2 + b_j + n} \right]^{\delta_{i,t}} \tag{9}$$

where $\delta_{i,t} = 1$ if brand i was bought at time t, and $\delta_{i,t} = 0$ otherwise. k_{ijt} denotes the number of times brand i was selected by time t in sequence b_j (i.e., the sequence of choices after the j^{th} renewal).

Since the time between new draws from $g(\theta)$ is geometrically distributed with parameter γ according to (4), then the likelihood function unconditional on the change vector becomes

$$L(k) = \sum_{c=0}^{g} \prod_{j=0}^{c} \prod_{t=1}^{b_j} \prod_{i=1}^{n} \left[\frac{\lambda_2\mu_i + k_{ijt} + 1}{\lambda_2 + b_j + n}\right]^{\delta_{i,t}} \gamma^c(1-\gamma)^{g-c} \tag{10}$$

which is the Multinomial-Dirichlet-Geometric (MDG) model.

Two special cases of the general likelihood function (10) can be developed. First, it can be shown that if changes in the probability vector never occur, (i.e., $\gamma = 0$), then the likelihood function becomes

$$L(k) = \left[\frac{\prod_{i=1}^{n} \Gamma(\lambda_2\mu_i + k_i + 1)}{\Gamma(\lambda_2 + g + n)}\right] \left[\frac{\Gamma(\lambda_2 + n)}{\prod_{i=1}^{n} \Gamma(\lambda_2\mu_i + 1)}\right] \tag{11}$$

since in this instance $c = 0$. When $\gamma = (c=) 0$, each sequential purchase we observe updates our knowledge about the probability vector. Moreover, each choice probability is estimated (irrespective of the criterion) by x_i/g, or the relative frequencies of choice. Note, furthermore, that the likelihood function expressed in (11) is a Multinomial-Dirichlet at the individual consumer's level. Analytically, it is similar to the traditional Multinomial-Dirichlet at the market level where the Dirichlet density captures the heterogeneity in the probability vector across the individual consumers (Bass, Jeuland, and Wright, 1976; Chatfield and Goodhardt, 1973, 1976). Note, however, that (11) results in a Multinomial-Dirichlet model at the market level under homogeneity conditions. Hence, despite the analytic identity, both models are quite different in behavioral premises. The danger of inferring individual choice behavior from well-fitting aggregate models (at market level) has been criticized before (see Bettman and Jones, 1972). A similar observation has been made with respect to the NBD model in the literature on accident-proneness (see Arbous and Kerrick, 1951).

A second special case of (10) assumes $\gamma = 1$, or a new vector is drawn at each purchase occasion. This implies $c = g$ and the likelihood function can be expressed as

$$L(k) = \prod_{t=1}^{g} \prod_{i=1}^{n} \left[\frac{\lambda_2 \mu_i + 1}{\lambda_2 + n} \right]^{\delta_{i,t}} . \tag{12}$$

where $\delta_{i,t} = 1$ if brand i was selected at t, and $\delta_{i,t} = 0$ otherwise. Hence, the likelihood function can be expressed as the product of the means of the corresponding univariate Beta densities underlying the Dirichlet density expressed in (3).

Estimation and Testing

Three sets of empirical results were derived. First, the parameters of the MDG model with the geometric parameter γ equal to 0 were estimated using the likelihood function expressed in (11). Second, the parameters of the MDG model with the geometric parameter γ equal to 1 were estimated using the likelihood function expressed in (12). Finally, the parameters of the model with unknown γ are estimated by defining the likelihood function on sequences of three consecutive purchases. In focusing on nonoverlapping triplets, an adequate number of degrees of freedom were retained for estimation and testing. Furthermore, underlying each triplet are eight change vector (v) combinations. Because draws from the optimal decision distribution are unobservable, all eight have to be considered and their corresponding choice probabilities have to be derived. Going beyond triplets would make analytic derivation of these probabilities cumbersome (note that for a sequence of k choice outcomes, there are 2^k change vector combinations each with a unique choice probability).

Two sets of tests were performed on the estimated models. The objective was (a) to evaluate the fit of the various model specifications postulated above, and (b) to test more general specifications against nested alternatives as a criterion of parsimony. The fit of the models was evaluated with a chi-square goodness-of-fit test (Massy, Montgomery, and Morrison, 1970, p. 33).

An interesting by-product of estimating the three models is derived from the obvious nesting of both the MDG (γ = 0) and MDG (γ = 1) models within the more general MDG (γ) model. In a likelihood ratio testing framework, the parsimonious or nested model serves as null hypothesis (Mood, and Graybill, 1978, p. 297). By performing model comparisons, not only are we able to determine the relative proportions of customers obeying the different assumptions about γ, but since the MDG ($\gamma = 0$) model has been extensively studied, we can infer its overall appropriateness from its frequency of being the "best" model for a sample of consumers.

With respect to discrimination, a comment must be made about the MDG model. Given the discrete time renewal scheme built into the model, the nonstationarity in the probability vectors (i.e., new draws over time) and the marginal Beta variance can be confounded. If an individual renews his probability frequently, the information provided in a choice sequence is with respect to the mean of the marginal Beta distribution. If the individual never renews his probability vector, his choice sequence leads us to update our knowledge about that particular probability vector. However, if that vector is close to the mean value of the marginal Beta density, a difficulty will arise in discriminating between both models. This will particularly be the case when the density $g(\theta)$ is very concentrated around the mean value. Hence, care has to be exercised in interpreting the relative fit of the models, especially when sample sizes are not substantially large. For a discussion on the issue of discrimination, see Sabavala and Morrison (1981, p. 641).

3. EMPIRICAL APPLICATION

Data

The data utilized in this study are from a split-cable television panel covering 200 weeks (see McGuire, 1977). The first 52 weeks were pre-test data, the test covered two years, and the final 44 weeks provided post-test data. The post-test data were not used in this study. The diary panel members were almost evenly split between test (399 families) and control (395 families).

The product studied is a low-cost, frequently-consumed grocery product which is available in different flavors. The flavor category examined constituted 61% of all product volume and has the most heavily advertised and widely recognized brands. Three brands dominated the flavor category. The advertising test represented an increase in advertising weight of about 50%.

At the individual family level, the number of non-overlapping triplets was small. At that level, the developed models were estimated in a binary framework. Accordingly, the Multinomial assumption was replaced by a Binomial assumption, and the Dirichlet assumption was replaced by a Beta assumption. Note that in a BBG framework, the special cases of $\gamma = 0$ and $\gamma = 1$ result in simple models. Specifically, for $\gamma = 0$ the model reduces to a simple Beta-Binomial model, and for $\gamma = 1$, the model essentially reduces to a Binomial model (i.e., when a consumer renews on each trial, his/her behavior becomes indistinguishable from a consumer who has a constant purchase probability equal to the mean of the Beta density).

The observed purchase sequence of each family was coded as choices of the test brand (denoted 1) versus all other brands (denoted 0). Some households were eliminated due to lack of sufficient data; as a result, the sample sizes were 258 controls and 161 experimentals. The difference in sample sizes is due to the number of weeks available to compute each group's purchase triplets. The control group families could be measured over 156 weeks (pre-test + test) while the experimentals had to be examined in the pre-test and test eras separately since the latter era could produce changes in behavior. Since an experimental household had to satisfy the information requirements for <u>both</u> periods, there was clearly greater opportunity to lose more experimental than control households.

Results: Model Testing

The goodness-of-fit results for the BBG models are summarized in Table 1. The entries in the table suggest that the fits for the three models were reasonably good. Note, however, that at each level of significance reported, the most general BBG (γ) model fitted the purchase histories for a larger number of families than any of its nested counterparts. At the family level, the BBG ($\gamma = 0$) and the BBG ($\gamma = 1$) were tested against the more general BBG (γ). The results (not shown) indicated that the BBG (γ) fit better than the BBG ($\gamma = 0$) for 70% of the control families at the 0.1 level with similar results for the experimental families.

Based on the likelihood ratio test results, Table 2 contains the number of families for which each model described the observed purchase sequence best. If the general model was significantly better than both nested models, it was selected as the best descriptive model. If the general model was not significantly better than one of the nested models or both of them, selection among the better model alternatives was done on the basis of the maximum value of the likelihood. In other words, if the general model was not significantly better than either of the nested models, choice among the nested alternatives was based on the greatest likelihood. Hence, parsimony did not enter directly into the classification process whose results are shown in Table 2. The results indicate that the majority of the families can be modeled by a BBG (γ = 1).

For the experimental families, Table 2 illustrates whether different models describe the choice sequence better before the test versus during the test. For 68% of the families the same model describes both sequences best. It is interesting to note, however, that for the majority of the families whose choice outcomes in the pre-test period can be modeled with a BBG (γ = 0), their choices during the test period are better described by a BBG (γ = 1). Hence, in contrast to the pre-test period, their probability vector changes from one choice occasion to the next. For the test period, the purchase sequence of less than 5% of the families can adequately be described by a BBG (γ = 0); for the pre-test period, the percentage of families whose choice sequence can be modeled with a stationary probability vector is closer to 20. Therefore, one impact of the increase in advertising exposures was to cause consumer behavior to become more unstable. This result must be interpreted with caution, however, since the shifts in behavior are not compared to the control group.

Results: Consumer Behavior

The parameter estimates of the family level analyses are summarized in Table 3. Only results from the control group are shown as there would otherwise be a large number of results and, in addition, our focus in this paper is not on evaluating the advertising experiment.

The reported kurtosis and skewness values in Table 3 indicate that the frequency distribution of the various estimates across the families in each instance is quite different from a normal bell-shaped curve. In particular, the utilities are not normally distributed across even the BBG (γ=1) group which is the largest. This has implications for models which make such normal distribution assumptions about utilities (e.g. the probit choice model). As can be seen, both families which have time-invariant probability vectors ($\gamma = 0$) and those which always change ($\gamma = 1$) are much greater disposed towards the brand of interest than the intermediate families as the mean utilities are much greater. The BBG (γ) families' variances in θ are also more responsive to changes in their loss function than the $\gamma = 1$ group as the differences in λ_2 show.

In panel A of Table 4, the control family groups classified according to best fitting model are defined in terms of demographic and behavioral variables. Of particular note is that households with unchanging preferences ($\gamma = 0$) are by far the lowest quantity purchasers of the category. This group appears to be empty-nesters as they have small families and do not spend as much on groceries as the other groups. The two groups with changing preferences look fairly similar except that the γ=1 group is much more loyal to brand 1 than the unknown γ group.

The regression results displayed in panel B of Table 4 also provide interesting results. Brand 1 seems to appeal to heavy buyers of the category. Higher income households seem to be more responsive in terms of variance around θ to changes in their loss functions than lower income families. Finally, the probability of a new probability vector being drawn is positively related to age, education, and purchase quantity while negatively related to income and loyalty. Previous literature and intuition support those results except that one would not expect older households to have greater γ's than younger.

4. CONCLUSION

In this paper, a probabilistic model of an individual's choice process was developed. The model considers explicitly the planning stage and the implementation stage of a choice decision. At the planning stage, the choice rule incorporates uncertain future events which could ultimately affect choice. Accordingly, choice behavior is fundamentally stochastic and the consumer decides on a density which characterizes revealed preferences at that stage. The probabilistic description of the actual choice at the implementation stage is modeled as a random draw out of the decision distribution specified at the planning stage.

The resulting choice model, a Multinomial-Dirichlet-Geometric model, resembles previously developed stochastic brand choice models. However, the approach taken to develop the model is fundamentally different in three ways. First, the underlying randomness of the choice process was a result of the model specification, not an a priori assumption. Second, the underpinnings of the model followed a well-established economic theory of rational random behavior. Finally, because of the underlying theory, the estimated parameters have economic interpretations. Thus, other similar models could be viewed as reduced-form models which can have good descriptive power but leave the parameters difficult to interpret.

Empirical results obtained at the family level indicate that the Multinomial-Dirichlet-Geometric model developed describes purchase histories rather well. For a frequently-purchased low-priced consumer product, the results indicate that the general MDG model fits choice behavior significantly better than a choice model which assumes stationary preferences (or purchase probabilities).

A caveat is that since estimation is performed at the consumer level, the discriminating power of the nested tests is low due to small sample sizes. Therefore, while the model development is a contribution to the literature, the implications based on the family level results are subject to small sample restrictions.

Table 1

CHI-SQUARE GOODNESS-OF-FIT RESULTS

	Significance Level	Model Specification BBG ($\gamma = 1$)	BBG ($\gamma = 0$)	BBG (γ)
Control Families (n = 258)	0.1	234*	238	241
	0.01	205	214	218
		Pre-Test		
Experimental Families (n = 161)	0.1	157	156	160
	0.01	142	143	145
		Test		
	0.1	143	152	153
	0.01	132	131	136

*Table entries are the number of families for whom the model in the column fit at the row level of significance.

Table 2

BEST DESCRIPTIVE MODEL BASED ON

LIKELIHOOD RATIO RESULTS

	BBG (γ = 1)	BBG (γ = 0)	BBG (γ)
Control Families (n = 258)	174	25	59

Experimental Families (n = 161)		Test BBG (γ = 1)	BBG(γ=0)	BBG (γ)	
	BBG (γ=1)	98	2	14	114
Pre-Test	BBG (γ=0)	19	5	1	25
	BBG (γ)	16	0	6	22
		133	7	21	

Table 3

FAMILY LEVEL ESTIMATION RESULTS: CONTROL FAMILIES

	No. of Families	Utility Parameter (μ_1)				Variance Responsiveness Parameter (λ_2)				Geometric Parameter (γ)			
		Mean	Variance	Kurtosis	Skewness	Mean	Variance	Kurtosis	Skewness	Mean	Variance	Kurtosis	Skewness
Control Families													
BBG (γ=1)	174	0.389	0.102	-1.277	0.406	24.506	469.05	-0.935	0.598	--	--	--	--
BBG (γ=0)	25	0.392	0.080	-0.975	0.538	--	--	--	--	--	--	--	--
BBG (γ)	59	0.205	0.078	1.636	1.693	42.885	3940.370	-0.792	1.079	0.570	0.202	-1.842	-0.372

Table 4

EMPIRICAL RESULTS: CONTROL FAMILIES

PANEL A

Demographics	$y = 1$	$y = 0$	y
Length at address (1-7 scale)	4.32	4.04	4.66
Family size	3.16	2.64	3.10
Number of children < 17	.79	.64	.82
Wife's age (1-8 scale)	5.20	5.20	5.21
Hours of TV watched* by wife/week	8.71	10.68	8.80
Working wife (1 = yes)	.40	.32	.43
Wife's education (1-7 scale)	3.28	3.56	3.39
Grocery expenditures* (1-10 scale)	3.79	3.44	4.03
Income (1-6 scale)	4.41	4.24	4.46
Quantity of product* purchased/week (oz.)	46.80	7.64	68.26
Loyalty* (% brand 1 purchases)	.43	.36	.30

PANEL B

Regressions

	Dependent Variable		
	μ_1 (n=258)	λ_2 (n=233)	γ (n=59)
Significant Independent Variables ($p < .10$)	Purchase quantity (+)	Income (+)	Wife's Age (+) Wife's Education (+) Income (-) Purchase quantity (+) Loyalty (-)
$\bar{R}^2$ (based on all demographics)	.78	.01	.60

*significant at $p < .10$

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