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Progress Report

Methodology of Preference Measurement

Prediction ... consumer choice

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QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES
Research and Development Command
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CONTRACT RESEARCH PROJECT REPORT

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SUMMARY

A model is presented for predicting the proportion of consumers who purchase each of three competing objects differing in price. The model is applied to predict proportions of consumers purchasing each of three luncheon entrees on several criterion days. Preference parameters are estimated from reponses to a food preference schedule by a least squares method of successive intervals; an iterative solution is utilized for estimating the utility of each price level. Results indicate that the model is tenable, and suggest a non-monotonic relationship between utility of price and monetary price level within the range of prices investigated.

A Model for the Prediction of Consumer Purchase and an Example of Its Use

I. The Problem

It is desired to formulate and to test a model for predicting the relative frequency of purchase of one object from three competing consumer objects at differing prices.

II. The Model

A. Prediction of choice. Let the preference score of the α^{th} individual for the i^{th} object be written

$$X_{i\alpha} = S_i + E_{i\alpha}, \qquad (1)$$

where S_i is the scale value of the i^{th} object, and $E_{i\alpha}$ is a random error variable with normal distribution $N(0, \sigma_i^2)$. Then the preference scores have the distribution

$$f(X_{i\alpha}) = N(S_i, \sigma_i^2) \; . \qquad (2)$$

For each object, i, the scale value S_i, and the discriminal variance σ_i^2, may be estimated conveniently by use of the method of successive intervals.

We define

$$z_{ij} = \frac{(X_{i\alpha} - S_i) - (X_{j\alpha} - S_j)}{\sqrt{\sigma_i^2 + \sigma_j^2}} \; . \qquad (3)$$

Then

$$f(z_{ij}) = N(0, 1), \qquad (4)$$

assuming only independence of $X_{i\alpha}$ and $X_{j\alpha}$, and, as was shown in Phase Report No. 4,

$$f(z_{ij}, z_{ik}) = N(0, 0, 1, 1, \sigma_i^2) \; . \qquad (5)$$

Since we have available estimates S_i, S_j, S_k, σ_i^2, σ_j^2, and σ_k^2, we can obtain the desired proportion of choice of object i over objects j and k by integrating (5):

$$P_{i > j,k} = \int_{C_{ji}}^{\infty} \int_{C_{ki}}^{\infty} f(z_{ij}, \; z_{ik}) dz_{ij} dz_{ik} \, , \qquad (6)$$

where

$$C_{ji} = \frac{S_j - S_i}{\sqrt{\sigma_i^2 + \sigma_j^2}} \, . \qquad (7)$$

The integral may be evaluated with use of tables for determining the volume of any quadrant of the bivariate normal distribution, which may be found in Part II of Karl Pearson's Tables for Statisticians and Biometricians.

B. Prediction of Purchase. Let the preference score for the α^{th} individual for the i^{th} object at price p be written

$$X_{ip\alpha} = S_i + U_p + E_{i\alpha} \, , \qquad (8)$$

where S_i is the affective scale value of object i, U_p is the subjective value (utility) of price p, and $E_{i\alpha}$, as before, is an error distributed as $N(0, \; \sigma_i^2)$.
Then

$$f(X_{ip\alpha}) = N(S_i + U_p, \; \sigma_i^2) \, . \qquad (9)$$

We may define quantities $z_{ip,jq}$ as in equation (3), where for S_i is substituted $(S_i + U_p)$, and for S_j is substituted $(S_j + U_q)$. The $z_{ip,jq}$ are distributed as (4), assuming independence of the $X_{ip\alpha}$ and the $X_{jq\alpha}$, and the joint distribution, as in equation (5),

$$f(z_{ip,jq}, \; z_{ip,kr}) = N(C, \; 0, \; 1, \; 1, \; \sigma_i^2) \qquad (10)$$

Once again to express the proportion of choice for object i at price p, over both object j at price q and object k at price r, that is $(P_{ip > jq,kr})$, we evaluate an integral of the form of (6), where each lower limit of integration takes the form

$$C_{jq,ip} = \frac{(S_j + U_q) - (S_i + U_p)}{\sqrt{\sigma_i^2 + \sigma_j^2}} \qquad (11)$$

However, in this case we do not have estimates of all parameters. While the method of successive intervals supplies estimates of S_i and σ_i^2, the U values remain unknown. Given three competing consumer objects and the proportion of purchase of each, yields three equations of the general form of (6) and allows an iterative solution for the three utilities U_p, U_q, and U_r (on a utility scale with an arbitrary zero point) by use of Pearson's tables of the bivariate normal distribution. Finally, if data are available for several sets of three consumer objects, each set containing one object at price p, one at price q, and one at price r, then the consistency of the various estimates provides a check on the model.

III. An Application

For this study competing entrees on a luncheon menu serve as stimuli. A seven-category successive category rating scale was mailed to each of the 430 faculty members who were also active members of the faculty club at the University of Chicago. The addressee was instructed to complete the form by placing a check mark to indicate the degree to which he liked or disliked each menu item. Included on the schedule were the names of the fifteen entrees served at the club during a criterion period. A total of 297 completed forms were returned, comprising 69% of those mailed.

Five criterion days were selected. On no criterion day was there a shortage of a luncheon item at the club, and on each day more than 100 members patronized the regular dining room facilities. The frequency of purchase of the three competing luncheon entrees on each of the five days serve as criteria.

From the preference ratings, approximate least squares successive intervals estimates were obtained for scale values and discriminal dispersions. Based upon these preference parameters, and upon the assumption of the normality of distributions of preference along the underlying scale continuum, one may utilize equation (6) to predict the proportion of consumers who would select each of three competing consumer objects. The resulting predicted proportions appear in Table 1, Model A. The comparison of these predicted proportions with actual observed proportions of choice, indicates that discrepancies are considerable. The average error in predicting proportions is .194.

The relatively poor fit of predicted to observed proportions may be partially attributable to the differing prices at which entrees were sold. On each criterion day, one of the three entrees was offered at $1.20, one at between $ .95 and $1.05, and the third at between $ .80 and $ .90. For convenience each of the three price levels is considered homogeneous, best represented by the prices $1.20, $1.00, and $ .85.

Using the prediction of purchase Model B, above, iterative solutions for the utilities of the three price levels were obtained for each of five sets of three equations. Each equation expresses $P_{ip > jq,kr}$ in terms of the preference and utility parameters. Each set of three equations provides a unique solution for $U_{.85}$, $U_{1.00}$, and $U_{1.20}$, on a scale with an arbitrary zero. The obtained estimates appear in Table 2. It will be noted that the most divergent values are those for criterion day 3. The lowest cost entree on that day is French fried smelt. That the day was a Friday appears to have added a determinant of purchase which is not included in the model.

It is also of interest to examine a plot of the mean utilities from Table 2 (Figure 1) to determine relative strength of negative utility for the three prices. $U_{.85}$ and $U_{1.20}$ consistently are more negative than $U_{1.00}$. While $1.20 is the least preferred price, $1.00 is a price preferred to $ .85. In other words, in this study, utility of price is not monotonically related to price.

Utilizing the mean values for the three utilities, final predictions are made, the results of which appear in the Method B column, Table 1. The improvement of fit is demonstrated by the relatively small average discrepancy of predicted from observed proportions, .031, and lends credence to the model.

The finding that faculty members, when lunching at the faculty club prefer paying $1.00 to paying $ .85 may come as a surprise to many of us. We might conjecture that the social psychology of publically ordering lunch at a table with colleagues provides a disposition away from the cheapest meal, or alternatively that $1.00 is an attractive round figure. The present study, of course, provides no evidence as to the source of the finding. Nor may we legitimately generalize the findings to any other situations. Nevertheless, it might not be surprising to find such non-monotonic relations between price and utility for numerous consumer commodities: for cosmetics, articles of clothing, household drug supplies--indeed for any items where the consumer evaluations of quality is difficult or impossible to make independent of the factor of price.

Table 1

Comparison of Predicted and Observed Proportions of Choices

Sample Size	Entree	Price	Proportion Observed Choice	Predicted Proportions Model A	Model B
116	Roast round of beef	$1.20	.405	.707	.402
	Smoked Tongue	1.00	.319	.120	.279
	Creamed mushrooms on toast	.85	.276	.173	.319
107	Fried chicken leg with country gravy	$1.20	.215	.510	.236
	Meat loaf with brown gravy	1.05	.505	.273	.473
	Welsh rarebit on toast	.80	.280	.217	.291
123	Roast leg of lamb	$1.20	.268	.623	.326
	Smoked Thuringer sausage	.95	.342	.200	.396
	French fried smelts with tarter sauce	.90	.390	.177	.278
102	Roast leg of lamb	$1.20	.441	.651	.351
	Braised ox joints	1.00	.304	.152	.314
	Baked beans	.80	.255	.197	.335
139	Roast round of beef	$1.20	.295	.586	.286
	Creamed chicken with hot biscuit	1.00	.439	.244	.448
	Apple fritters, bacon, and syrup	.85	.266	.170	.266
	Mean $d_{(pred-obs)}$			.194	.031

Table 2

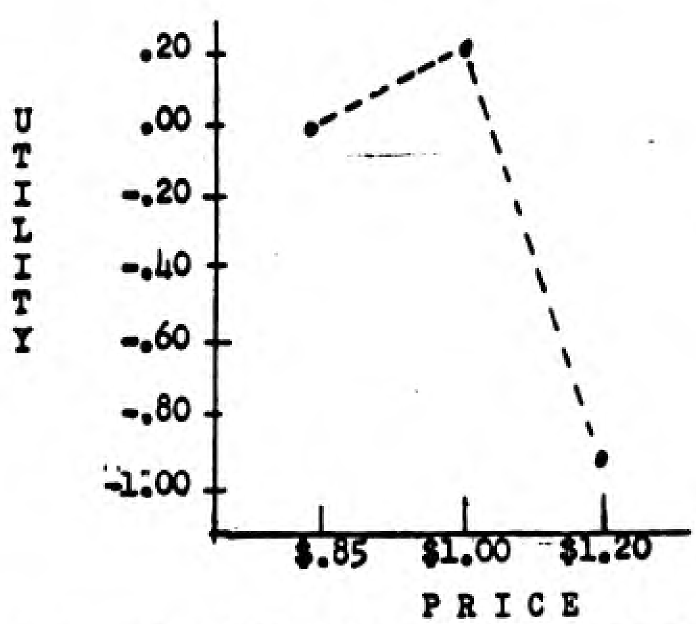
Estimates of Utility Values*

Criterion Day	$U_{1.20}$	$U_{1.00}$	$U_{.85}$
1	-.810	.420	.000
2	-.967	.265	.000
3	-1.395	-.257	.000
4	-.547	.353	.000
5	-.916	.154	.000
Mean	-.927	.187	.000

* $U_{.85}$ is arbitrarily assigned zero utility.

Figure 1

Final Estimate of Utility of the Three Prices*



* $U_{.85}$ is arbitrarily assigned zero utility.