HEDONIC PRICES FOR A NONDURABLE GOOD: THE CASE OF BREAKFAST CEREALS

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Abstract—Numerous studies have estimated hedonic price functions for durable goods. In this paper we apply the methodology to breakfast cereals, a nondurable good. We employ maximum likelihood to estimate the hedonic price functions using data from three large supermarkets. The price function depends on characteristics that provide taste, nutrition and convenience to consumers, and the estimates yield insights into pricing policies, consumer preferences and consumer use of information.

I. Introduction

Since Griliches' (1961) early work examining quality changes using hedonic price indexes for automobiles, numerous empirical studies have estimated hedonic prices for characteristics of durable goods such as houses, automobiles and appliances. But nondurable goods also can be defined by their inherent characteristics. Moreover, depending on the good, the estimated implicit prices may provide useful insights about consumer preferences, the structure of the market in which the good is sold, and how consumers gather and react to information that describes the good.

In this paper we apply the hedonic technique to estimate implicit prices of breakfast cereal characteristics. We chose cereals because consumers can gather information easily about cereal characteristics either through experience, advertising or package labeling. Our results provide insights about manufacturer and retailer pricing policies, consumer preferences, the premiums consumers pay for the convenience of ready-to-eat breakfast cereals, and consumer response to nutritional labeling. The latter is particularly important for policies on information disclosure.

II. Empirical Analysis

To motivate the empirical work, we modify Rosen's (1974) theory by assuming that consumers derive utility from services, s, that the characteristics of the cereal provide and from a composite good X. Thus, utility is represented by the function

$$U(s_1, \ldots, s_m, X).$$

Examples of these services might be the taste and nutrition of cereals. Let $z = (z_1, \ldots, z_n)$ be the vector of characteristics and let $s_h(z_1, \ldots, z_n)$ be service h, $h = 1, \ldots, m$. A characteristic can enter positively into one service and negatively into another. For example, the sugar characteristic may increase the taste service and decrease the nutrition service. Standard utility maximization shows that the marginal implicit price of a characteristic measures the value of an additional unit of the characteristic relative to an additional dollar's worth of other goods. Remembering that there may be some characteristic, z_k, that enters positively into one service function and negatively into another, the marginal implicit price of z_k may be positive over some range of z_k and negative over another. In equilibrium, the marginal implicit prices represent the joint envelope of the consumers' value functions and the firms' offer functions.

The data for the project were gathered in 1985 from four large supermarkets in the Portland, Oregon area: Zupans (an independent grocer), Fred Meyer (a West Coast chain), and two Safeway stores (a national chain). We gathered data from several stores to look for differences in the hedonic price function that may suggest that stores set prices based on the preferences of the customers they serve. For example, marginal willingness to pay for a characteristic may vary across income levels. In addition, gathering data from two Safeway stores gives an indication of the control an individual store has over price setting.[1]

Price and characteristic information were collected for all cereals found at each of the stores. If a cereal came in several different sizes, each size made up one observation. The dependent variable is price per serving (*PPS*). The characteristics comprising the set of independent variables were chosen based on the information presented on each cereal package. Each characteristic contributes to one or more of three services

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[1] One Safeway store was located in a high income neighborhood and one in a low income neighborhood; therefore, they may serve different classes of customers.

TABLE 1.—DEFINITIONS OF CHARACTERISTICS

Characteristic	Services[a]	Definition
VIT	*N, C*	(vitamin A + vitamin C + thiamine + riboflavin + niacin + iron)/6
NS	*C*	number of servings in box
SUC	*N, T, C*	grams of sucrose and other related sweeteners in one serving
FIB	*N, T, C*	grams of fiber in one serving
NAT	*N*	1 if the cereal claims to be natural
FRUIT	*N, T, C*	1 if the cereal contains fruit
*TEX*1	*T*	1 if flakes
*TEX*2	*T*	1 if puffed
SOD	*N, T*	milligrams of sodium in one serving
PRE	*N, C*	1 if cereal contains preservatives
*GR*1	*N, T*	1 if corn
*GR*2	*N, T*	1 if rice
*GR*3	*N, T*	1 if oats

[a]*Services*: *N* = Nutrition; *T* = Taste; *C* = Convenience.

assumed to be positively related to utility: nutrition, taste and convenience. Table 1 provides a list of characteristics with their definitions and associated services.

Variables appearing in the nutritional information on the cereal package and included in our hedonic price equation are grams of sucrose, *SUC*; milligrams of sodium, *SOD*; grams of fiber, *FIB*; and the average of the recommended daily allowance (RDA) of five vitamins plus iron, *VIT*. We expect *SUC* and *SOD* to be associated negatively with nutrition while *FIB* contributes positively toward nutrition. However, *SUC*, *SOD*, and *FIB* also enter into the taste service, and for many consumers these variables are likely to enter with a sign opposite from the nutrition service. Thus, the signs of the implicit prices of these characteristics cannot be determined a priori. *VIT*, on the other hand, enters into the nutrition service and convenience service and we expect it to enter positively in both. *VIT* enters the convenience service because consuming vitamins in a cereal is easier than consuming vitamins and cereal separately. This may be especially important for children. *SUC* and *FIB* also enter the convenience service positively, but this will not alter the a priori ambiguous signs of their implicit prices.

Two variables appearing in the nutrition table of a cereal package but not included in the hedonic price equation are calories and grams of fat. Grams of fat are not included because the fat content varies little among cereals. Calories are not included in the hedonic price function because they are determined by other variables included in the function, namely *SUC* and *FIB*. Since including them would cause serious multicollinearity problems, we estimate a reduced form equation excluding calories.

NAT indicates that the word natural appears somewhere on the box, and it enters the nutrition service only. If consumers perceive that *NAT* is positively associated with health, its implicit price should be positive. *PRE* measures whether the cereal contains preservatives where the presence of preservatives in a cereal is revealed in the ingredient list. Preservatives enter negatively in the nutrition service and positively in the convenience service, so that the sign of its implicit price is ambiguous.

FRUIT measures the presence of fruit. We expect its implicit price to be positive since it should enter positively into the taste, convenience, and nutrition services. The major type of grain used in the cereal (wheat, rice, corn, oats) is a characteristic that may affect both the taste and nutrition. Three dummy variables were constructed to measure the grain; *GR*1, *GR*2, and *GR*3. No a priori signs are hypothesized for their implicit prices. Because cereals come in a variety of textures, we categorize them according to whether they are flakes (*TEX*1), puffed (*TEX*2), or all others. These variables enter the taste service only and we predict no a priori signs on their implicit prices. One other independent variable was included that is not associated with health or taste. *NS* is the number of servings in a box and it is included to measure the inconvenience or convenience of buying a larger box. NS^2 is also included in the hedonic equation.

Box-Cox techniques have been used extensively in recent years to estimate hedonic price equations since the appropriate functional form cannot be specified on theoretical grounds. We used the linear Box-Cox functional form[2]

$$PPS^{(\lambda)} = \alpha_0 + \sum \alpha_i X_i^{(\gamma)} \tag{1}$$

where the Box-Cox transformations, $PPS^{(\lambda)}$ and $X^{(\lambda)}$,

[2] Cropper et al. (1988) find that the linear Box-Cox model performs better in estimating the hedonic price function than the quadratic form when some attributes are unobserved or are replaced by proxies.

have the form

$$V^{(\delta)} = (V^{\delta} - 1)/\delta, \qquad \delta \neq 0$$
$$= \ln(V), \qquad \delta = 0.$$

Equation (1) was estimated by maximizing the truncated normal distribution for the Box-Cox transformation suggested by Maddala (1983). To estimate unbiased standard errors of the parameters, the covariance matrix of the parameter estimates was derived from the second derivative matrix of the likelihood function according to Spitzer (1982).[3]

III. Results

In table 2 we present estimated coefficients and their t-statistics and the marginal implicit prices for all characteristics evaluated at their means for each of the three distinct stores. We have included results from only one Safeway store since we were unable to reject the hypothesis that the Safeway stores came from the same population. In fact, 92% of the prices for the same cereal in the two stores were the same. There are, however, interesting differences across the distinct stores. This may indicate that the control the manufacturers have in price setting may be partially overcome by retail pricing policies that set price according to the demands of the consumers they serve.

The coefficient on *VIT* is positive and highly significant across all stores. The sign on *NAT* is also positive across all stores but only significant at the 15% level in one store. *FRUIT* carries the expected positive sign and is significant in all three stores. The coefficient on *FIB* is negative and significant across all stores, suggesting that the taste service dominates the nutrition service for this characteristic. *PRE* carries a positive sign, but is insignificant across all stores. Coefficients on *SOD* are negative for two stores but insignificant across all stores while coefficients on *SUC* are all positive and significant.

For all stores the coefficients on the grains are significant only for oats. The positive sign indicates that, *ceteris paribus*, some consumers are willing to pay more for cereals made from oats. For textures, the positive and significant coefficient on *TEX*2 across all stores indicates that some consumers pay more for puffed cereals.

Finally, the coefficients on *NS* and NS^2 are negative and positive, respectively, and significant across all stores. There are economies in producing larger boxes, and the lower per serving prices compensate at least some consumers enough to offset any inconvenience.

The results for *SUC*, *SOD* and *PRE* can be contrasted to recent surveys on the diets of Americans. The surveys indicate that many consumers perceive salt, sugar and preservatives as hazardous to their health, and one in six shoppers regularly purchases sodium-modified products. The insignificant coefficients on *SOD* and *PRE* are not consistent with these stated attitudes; however, at least for *SOD* this may be because the quantity of sodium in cereal is small relative to many other foods. The positive and significant coefficient on *SUC* is at odds with the survey results, but it is consistent with a U.S.D.A. Food Consumption Survey (1990) that found Americans consuming sweeteners at a higher rate than any time in this century.

If sucrose, fruit, fiber and vitamins enter into the convenience service as well as the nutrition service, then consumers may be paying more for them than if the characteristics were obtained in a substitute form. To examine this, consider that a consumer can either take a vitamin tablet or eat a cereal that gives the desired RDA level. From a sample of vitamin tablet prices at several retail outlets, we computed the average price per percent RDA of a vitamin tablet containing the same or nearly the same vitamins as those used to compute *VIT*. These tablet prices ranged from 0.012 cents to 0.025 cents. On the other hand, the price per percent RDA found in the mean cereal ranges across stores from 0.055 to 0.068. Thus, consumers pay a premium for convenience ranging from 2.2 to 5.7 times what they would pay for the same vitamins in tablet form. The wide variety of fruits, fibers and sweeteners available precluded similar comparisons for these characteristics.

Implications for the Uses of Information

A widely accepted notion is that providing consumers with information about the products they buy increases the efficiency of the marketplace. There are

[3] There is a possibility that the errors corresponding to different sizes of a specific cereal may be correlated within one store because of random exogenous factors that similarly influence the price of a given cereal across sizes. For example, the price of a brand of cereal may depend on the assortment of other cereals and substitute products in a specific grocery store. If this type of correlation exists, the maximum likelihood estimation above will not yield unbiased estimates of the standard errors. Dubin (1988) examines this type of correlation in the form of spatial autocorrelation when estimating hedonic functions for homes. In an earlier version of this paper, we addressed this problem by estimating a linear hedonic price function using generalized linear squares (GLS). A linear function was used on the basis that the results in table 2 did not lead us to reject the linear model at the 0.01 level. To carry out the GLS procedure, we estimated the error variance-covariance matrix, Ω, as outlined in Kmenta (1986). We found that not accounting for the correlation between the errors resulted in upwardly biased standard errors although the bias was very small. Although theoretically possible, we did not estimate the Box-Cox model taking into account this correlation because of the computational complexity of the problem which requires repeated inversion of a large matrix, and because the correlation did not appear to be a serious problem here.

TABLE 2.—COEFFICIENTS, t-STATISTICS, AND MARGINAL IMPLICIT PRICES

	Coefficients and t-statistics			Marginal Implicit Prices		
	Zupan	Fred Meyer	Safeway	Zupan	Fred Meyer	Safeway
Constant	35.86[a]	35.71[a]	36.00[a]			
	(2.27)	(6.82)	(3.90)			
NS	−2.27[a]	−4.42[a]	−3.59[a]	−0.51	−0.51	−0.46
	(−1.96)	(−5.13)	(−2.18)			
VIT	0.194[a]	0.180[a]	0.187[a]	0.059	0.055	0.068
	(3.29)	(4.96)	(2.25)			
FIB	−0.304[a]	−0.335[a]	−0.351[a]	−0.192	−0.219	−0.214
	(−2.20)	(2.58)	(−1.98)			
SUC	0.450[a]	0.426[a]	0.420[a]	0.196	0.190	0.193
	(2.04)	(3.68)	(2.91)			
SOD	−0.002	0.0002	−0.0003	−0.0004	0.00004	−0.00007
	(−0.167)	(0.024)	(−0.03)			
FRUIT	2.67[a]	2.21[a]	2.60[a]	1.89	1.62	1.72
	(2.60)	(2.85)	(2.79)			
NAT	0.700	0.287	0.170	0.500	0.213	0.112
	(1.65)	(0.503)	(0.260)			
PRE	0.620	0.820	0.450	0.440	0.601	0.300
	(1.13)	(1.40)	(0.812)			
*TEX*1	−0.087	0.293	−0.100	−0.062	0.215	−0.006
	(−0.15)	(0.475)	(−0.014)			
*TEX*2	1.55[a]	1.94[a]	1.83[a]	1.10	1.41	1.21
	(1.99)	(2.68)	(2.15)			
*GR*1	0.221	−0.172	0.280	0.156	−0.125	0.185
	(0.337)	(−0.294)	(0.378)			
*GR*2	0.808	1.08	1.53	0.575	0.791	1.01
	(0.905)	(1.34)	(1.56)			
*GR*3	2.59[a]	3.10[a]	2.80[a]	1.84	2.27	1.85
	(2.57)	(3.42)	(2.23)			
NS^2	0.165[a]	0.202[a]	0.128[a]			
	(2.07)	(5.10)	(1.64)			
λ	1.13	1.11	1.15			
	(5.68)	(5.32)	(6.68)			
γ	0.74	0.73	0.81			
	(4.21)	(5.32)	(4.68)			
N	101	99	96			
Log of Likelihood	−183.98	−179.24	−172.75			

Note: t-statistics are in parentheses.
[a] Significant at the 0.05 level.

strong incentives for consumers to gather information and increase the efficiency of their purchase decisions. However, disclosure is costly, and as enumerated by Beales, Craswell and Salop (1981), market failures in the provision of information may prevent an optimum amount or quality of disclosed information. The federal government has made disclosure mandatory for many product groups including nutritional information on any food product that is nutritionally fortified.

Disclosure, mandatory or voluntary, will be useful only if consumers gather and use the disclosed information; however, consumer reaction to information often is not well understood (Beales, Craswell and Salop 1981). Our results can be used to better understand whether consumers are reading the information printed on cereal boxes.

The *VIT* characteristic is useful for our purposes. It does not enter the taste service so experience is not a likely explanation for the significant and positive marginal willingness to pay. RDA vitamin information always appears in the nutritional information on the side of the box and in some cases a general description (e.g., "high in vitamins"), particularly for heavily fortified cereals, is displayed in the front. To test whether the general description is important, we replaced *VIT* with a variable indicating whether vitamin information appeared on the front.[4] The coefficient on this variable was positive but insignificant. This result suggests that the detailed RDA information is important. Moreover, although advertising is another source of information on vitamin rich cereals, general descriptions are used

[4] Two different variables were substituted, one at a time, for *VIT*. A dummy variable was constructed where a value of 1 was assigned if any vitamin information appeared on the front. The second variable measured the number of vitamins and minerals noted on the package front.

in lieu of detailed RDA information. Therefore, our results support the hypothesis that at least some consumers are reading nutritional labeling to obtain RDA information.

IV. Conclusions

The estimation of hedonic price functions for durable goods has proved to be a useful methodology. In this paper, we applied the methodology to breakfast cereals, a nondurable good. We expect that for many nondurable goods, information describing the goods' characteristics will be lacking and hedonic price estimates will yield poor results. But for breakfast cereals, information is readily available, and our results proved useful for analyzing pricing policies, consumer preferences, and the use of information and package labeling. The hedonic techniques could prove to be a practical method of measuring consumer response to disclosure of information, if the researcher gathers information on market prices and the characteristics of the good over several time periods to track the implicit prices of the characteristics for which information is disclosed. Combining this information along with knowledge of consumer preferences can reveal whether or not the information is used.

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JOINT ADOPTION OF MICROCOMPUTER TECHNOLOGIES: AN ANALYSIS OF FARMERS' DECISIONS

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Abstract—This study presents an econometric examination of the joint decisions of farmers on the adoption of a microcomputer and (or) purchased computers services. The characteristics of a farmer—schooling, age, off-farm work—are shown to be important variables for explaining the odds of adopting purchased computers services only, a microcomputer only, and both computer technologies. Adoption of computer technologies seems to occur in farming operations where they can be expected to greatly enhance the efficiency.

Recent advances in microcomputer technology and availability of low cost microcomputers have greatly increased the potential for information storage and analysis by small firms. The use of on-site microcomputers and of hired computer services can increase the profitability of farming operations (Sonka, 1983). The need for capability to utilize more sophisticated information and data storage and processing equipment has increased as U.S. farm businesses have become larger and more complex.

This study examines the joint decisions by farmers for adopting microcomputers and computer services for their farm businesses. Purchased computer services are services acquired outside the farm, such as accounting or farm record analyses, that involve the use of a computer. These services do not generally require the use of a computer on the farm. A multivariate logit specification of this adoption model is fitted to data obtained from a survey on ownership and use of different computer-related technologies. The results show that a farmer's schooling and his farm's structure have

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