HOUSEHOLD NUTRIENT DEMAND: USE OF CHARACTERISTICS THEORY AND A COMMON ATTRIBUTE MODEL

David B. Eastwood, John R. Brooker, and Danny E. Terry

Abstract

A characteristics model, which assumes goods generate a common set of attributes but no unique attribute, is described. The model yielded two equations which were estimated. One was a set of hedonic price equations in which the price paid for each food purchased was a function of imputed attribute prices. This set of equations was estimated at the household level. Nutrient demand equations were estimated across households. Imputed prices, income, and household characteristics including location, size, education, age distribution, and race affected nutrient demand levels.

Key words: attribute, characteristic, hedonic, price, nutrient demand, utility.

Traditional consumer behavior and demand theory has as its basic concept the idea of a product, a good, or a service generating utility. This theory leads to a model of consumer choice in which market goods are the decision variables, given a collection of products and/or services, their respective prices, and a budget constraint. An alternative approach, characteristics theory, assumes that utility is generated by the characteristics, or attributes, which goods and services possess. This approach changes the basic arguments of the utility function. Instead of utility being a function of products, utility becomes a function of the attributes provided by these products. Consumer marketplace behavior, then, is a result of utility maximizing choice in terms of bundles of attributes. Goods are distinguished by their combinations of attributes and the demand for goods is derived from the demand for attributes.

The first of two basic versions of the characteristics model introduced a utility function containing qualities as separate variables in addition to the traditional quantity variables (Hanemann; Houthakker). Houthakker assumed that a commodity could be described by two variables, physical quantity and quality. He stated that commodities with different characteristics were treated as the same good but having variable quality. Consumers could choose the quality of the good explicitly and, by their choice of quality, they could determine its price.

The second basic version of the characteristics model incorporated two fundamental propositions (Lancaster, 1966 and 1971). The first proposition was that all products possess measurable attributes relevant to the choices which individuals make among different collections of products. The relationship between a given quantity of a product and the characteristics which it possesses is essentially a technical relationship, depending on the measurable properties of the product and the consumer's knowledge as to what the product can do and how the product can generate characteristics. The second proposition was that individuals differ in their valuations of different characteristics, rather than their assessments of the levels of attributes produced by the various products. Individuals possess preferences for collections of characteristics. Preferences for products are indirect in the sense that products are valued because they provide the characteristics sought.

A model similar to Lancaster's (1966 and 1971), but without the controversial assumptions, was developed by Ladd and Suvannunt, Suvannunt, and Ladd and Zober.

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Their model, the Consumer Goods Characteristic Model (CGCM), yields two hypotheses: (1) for each product consumed, the price paid by a consumer equals the sum of the consumer's implicit marginal monetary values of the product's characteristics, where the marginal monetary value of each characteristic equals the quantity of the characteristic obtained from the marginal unit of the product consumed multiplied by the marginal implicit price of the characteristic and (2) the consumer demand functions for products are affected by characteristics of the products (Ladd and Suvannunt, p. 504). The CGCM allows for a unique attribute for each product.

The objective of this paper is to propose a new characteristics model and to report on its estimation. The model is a variant of CGCM which excludes the unique attribute term. This is based on the assumption that all the relevant attributes are common to the goods consumed. This is more suitable for the analysis of commodity groups such as food. Estimates of the model's hedonic price equations and attribute demand equations are presented. The data permitted estimation of household-specific implicit prices. Such estimates have not appeared in the existing characteristics model literature. These estimated prices are used along with other household variables as determinants of the levels of nutrient demand. The new model's empirical results are discussed in terms of their implications regarding consumer purchases of food.

MODEL DEVELOPMENT

Terry has developed a version of CGCM assuming there are m common attributes for n goods. The utility function, U, for a representative consumer is:

$$(1)\ U = U(X_1, X_2, \ldots, X_m).$$

X_j is the total quantity of the j^{th} attribute derived by the consumer from the consumption of all products. The consumer evaluates tastes and preferences in terms of the total product attributes obtained. The consumer's level of each attribute depends on the quantities of products consumed, Q_i, and on the exogenous attribute input-output coefficients associated with a unit of each product, the x_{ij}:

$$(2)\ X_j = f_j(Q_1, Q_2, \ldots, Q_n, x_{1j}, x_{2j}, \ldots, x_{nj}),$$

where x_{ij} is the quantity of the j^{th} attribute obtained from a unit of product i, and X_j is endogenous. Substituting equation (2) into equation (1) yields the level of utility as a function of the input characteristics and quantities of market goods:

$$(3)\ U = U(Q_1, Q_2, \ldots, Q_n, x_{11}, \ldots, x_{nm}).$$

If it is assumed that the individual consumer has a fixed money income (I), the budget can be written as:

$$(4)\ \sum_{i=1}^{n} P_i Q_i = I,$$

where P_i ($i = 1, \ldots, n$) is the unit price of the i^{th} product consumed. No restrictions are placed on the values of utility associated with each x_{ij}. Therefore, it is possible that a certain attribute in a specific product can lead to disutility. If the product is to be purchased, other attributes with positive utilities associated with them must at least be equal to the disutility.

The consumer maximizes equation (3) subject to equation (4). Assuming the equations are twice continuously differentiable, the first order conditions can be obtained from the Lagrangian expression (5):

$$(5)\ L = U + \lambda(I - \sum_{i=1}^{n} P_i Q_i),$$

with λ being a Lagrangian multiplier. Since the x_{ij}'s are exogenous from the consumer's viewpoint, equations (2) and (3) indicate that consumer choice centers on the Q_i. Therefore, the first order conditions are obtained from the partial derivatives of L with respect to Q_i ($i = 1, \ldots, n$) and λ. Rearranging the necessary conditions and recognizing that λ is the marginal utility of income leads to equation (6) which is similar to Ladd and Suvannunt except that there is no unique attribute term;

$$(6)\ P_i = \sum_{j=1}^{m} \frac{\partial X_j}{\partial Q_i} \bullet \frac{\partial I}{\partial X_j}\ (i = 1, \ldots, n),$$

where $\frac{\partial}{\partial X_j} = \frac{\partial U}{\partial X_j} \bullet \frac{\partial I}{\partial U}$. That is, $\frac{\partial I}{\partial X_j}$ is the marginal rate of substitution of income for the j^{th} attribute. It is the marginal implicit price paid for the j^{th} attribute or the marginal valuation the consumer has for an incremental unit of an attribute. Equation (6) is the hedonic price equation for the unit price of market good i. It indicates that a consumer alters purchases of goods so the market prices paid by the consumer equal the sum of the marginal money values of the characteristics. An empirical interpretation of equation (6) is that the product price is related to its characteristics (Ladd, p. 31). The functional form of equation (6) has been examined previously (Griliches; Kravis and Lipsey; Morgan). No consensus has been reached as to the most appropriate functional form. If a linear form is selected, the relationships in equation (6) can be converted into an empirically estimable form, where

$$\frac{\partial X_j}{\partial Q_i} = x_{ij} \text{ and } \frac{\partial I}{\partial X_j} = \beta_j,$$

or

$$(7)\ P_i = \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_m x_{im}.$$

This linear hedonic price equation can be easily interpreted. Each x_{ij} is the marginal amount of attribute j associated with a unit of Q_i (e.g., the amount of protein in a pound of steak). β_j is the marginal implicit price of an attribute and is assumed constant.

The model has been developed in terms of a representative household. It can be adjusted to allow for different households having different marginal valuations of attributes and for households paying different prices. The former is assumed to be a result of socioeconomic factors affecting the utility derived by a household. The latter reflects price variations which occur within and across shopping areas. Allowing for h (h = 1, ..., H) different households, equation (7) becomes:

$$(8)\ P_i^h = \sum_{j=1}^{m} \beta_j^h x_{ij},$$

where P_i^h is the price per unit paid by a household for the i^{th} product and β_j^h is the implicit price the household is willing to pay for an additional unit of attribute j from the products. The relationships between prices and quantities of attributes for products consumed by a particular household are represented by equation (8).

Another set of empirical relationships can be derived, the attribute demand equations. Each food generates a vector of attributes, so the total consumption of an attribute depends on the Q_i purchases. Optimal Q's are defined by the first order conditions. Since the first order condition equations (6) and (7) contain prices and income, just as in traditional demand analysis, attribute demand equations can be readily seen as functions of prices and income. The characteristics model has an additional set of exogenous variables, x_{ij}, that have a role in demand equations. If the r^{th} product has the quantity of the s^{th} attribute that it possesses either increased or decreased, it will affect the quantity of the i^{th} commodity consumed. Suvannunt has shown that a change in an attribute has an effect on the quantities demanded. Thus, even though prices and income remain constant, household purchases of a product can vary if some producer varies at least one characteristic input-output coefficient. Household demands for attributes depend, consequently, upon prices, income, and product characteristics:

$$(9)\ X_j = d_j(P_1, P_2, \ldots, P_n, I, x_{11}, x_{12}, \ldots, x_{1m}, x_{21}, x_{22}, \ldots, x_{2m}, \ldots, x_{n1}, x_{n2}, \ldots, x_{nm}).$$

Each P_i can be expressed as a function of characteristics prices (β_j) or:

$$(10)\ X_j = d_j(\beta_1, \beta_2, \ldots, \beta_m, I, x_{11}, x_{12}, \ldots, x_{nm}).$$

The household's total demand for an attribute is affected by the implicit marginal prices of product attributes, income, and attribute input-output coefficients.

If producers do not vary characteristic input-output coefficients over the time period being considered, equation (10) becomes:

$$(11)\ X_j = d_j(\beta_1, \beta_2, \ldots, \beta_m, I).$$

Assume that equation (11) can be approximated by a linear relationship,

$$(12)\ X_j = \delta_0 + \delta_1\beta_1 + \delta_2\beta_2 + \ldots + \delta_m\beta_m + \delta_I I,$$

where X_j is the total quantity of attribute j consumed by household h from numerous products, β_j is the household's marginal implicit price for attribute j, and the δ's are the parameters to be estimated. Equation (12) states that the household's total demand for an attribute is affected by the implicit prices of all attributes as well as income.

By allowing for preference structures to vary by households, the demand for attributes becomes a function of each household's marginal implicit price (β_j^h), income (I^h), and a vector of household socioeconomic characteristics (V). That is,

$$(13)\ X_j^h = a_o + \delta_1\hat{\beta}_1^h + \delta_2\hat{\beta}_2^h + \ldots + \delta_m\hat{\beta}_m^h + \delta_I I^h + \delta_V V^h.$$

In addition to income, the bonus value of food stamps may be included to reflect the increased ability of low income households to purchase food alone (Chavas and Keplinger).

DATA

The common attribute model can be applied to estimate household food nutrient demands. Assume that the attribute demands are weakly separable with respect to food versus all other goods and that for a given household the supplies of foods are perfectly elastic. Also, assume that an additive error term has been included in equations (8) and (13). The 1977-78 Nationwide Food Consumption Survey (U.S. Department of Agriculture) comprises a data set which permits estimation of these equations. The strategy used to estimate the equations is a blend of the theoretical properties of the model and the available data. Consequently, the data are described, then an explanation of the estimation procedure is given.

The spring portion of the NFCS is used with data for approximately 3,300 households (U. S. Department of Agriculture.). Missing data required exclusion of some households. Other households were excluded because they did not purchase enough food items to estimate equation (8). More specifically, the nutrient content of food consumed for 14 nutrients were provided with the data. In order to have sufficient degrees of freedom to begin preliminary estimation, only those households which purchased 20 or more food items during the survey period were used. Since fewer than 200 households were eliminated in this step, the 20-food item requirement alone was felt to cause a very small selection bias. Altogether, 1,138 households were eliminated, resulting in a sample size of 2,164. Restriction to the spring period eliminated estimation problems associated with seasonal variations in market prices, availability of homegrown foods, and different seasonal life-styles. This was also necessitated by estimation constraints. For the spring period alone, over 100,000 food items were involved in a pooled household analysis.

Multicollinearity among the 14 nutrients necessitated aggregation. For example, the correlation across food items for thiamine and riboflavin was .64. They are part of the B vitamin complex, so thiamine, riboflavin, niacin, and vitamins B6 and B12 are combined into vitamin B. Minerals represented calcium, iron, magnesium, and phosphorus. Pairwise correlations among the independent variables containing the aggregates were considerably lower, suggesting that the problems of multicollinearity were decreased (.38 or less). Of course, these were only pairwise correlations and other linear combinations could exist. Further tests did not appear warranted in the interest of retaining a variety of nutritional characteristics and there being no well defined rationale for further aggregation. The aggregation which did occur is also consistent with the view that consumers assess broader groups of nutrients (Weimer, pp. 20-23).

Table 1 lists the socioeconomic variables used. Table 2 lists the nutrients in the left-hand column. Variables generally included in V are household size, ethnic background, educational attainment of the homemaker, homemaker employment status, location of the household, and number of meals.

Household size may measure returns to scale as well as variations in attribute demand due to differences in household size. Not only is size important, but the age distribution of household members can have an impact (Blaylock and Burbee; Smallwood and Blaylock). Larger households, *ceteris paribus*, are expected to consume greater amounts of nutrients. Those households having higher concentrations of members in higher growth and activity periods are expected to consume more nutrients. For example, teenagers and young adults through middle aged adults are expected to consume relatively more than other age groups.

Ethnic backgrounds may influence attribute demand, so race was incorporated. Black households have been found to consume fewer carbohydrates, calcium, and thiamine than white or other race households. Black households have also been found to consume less vitamin C, iron, and more fat than other race households (Adrian and Daniel; Blaylock and Burbee; Burk; Raunikar et al.; Smallwood and Blaylock).

Educational attainment of the homemaker was intended to reflect possible variations in the ability of the homemaker to relate food consumption to attribute demand. It is expected, *ceteris paribus,* to have varied impacts on nutrient demand. Households in which homemakers have higher levels of education are hypothesized to have higher levels of nutrient consumption such as protein and vitamins and lower levels of consumption of carbohydrates and fats (Adrian and Daniel; Scearce and Jensen).

Whether the homemaker worked outside of the home was included to account for a more restrictive time constraint for home production activities and an increase in food away from home due to job related activities. Lower levels of nutrients consumed from food at home are hypothesized to occur when the homemaker has marketplace employment.

Location may also affect nutrient demand through changed home production possibilities, access to food stores, and factors such as availability (Burk). Consequently, urban households may be able to be more selective in food purchases, thereby having more control over nutrient levels. Higher levels of protein and vitamins and lower levels of fats are expected for urban households since the first two are considered to have positive effects on health while the third has some negative effects.

Another consideration is the total meals consumed by the household to account for the number of meals at home, away from home, guest, skipped, and free meals. Assume the typical person eats three meals per day. Then, the measure frequently used (e.g., LaFrance) is the difference between the total number of meals served and the associated day-equivalent number of meals served for the household members.

CGCM, as well as the common attribute version outlined previously, assumes constant marginal implicit prices. The data enable us to estimate β_j^h for each household. These do not change for a specific household, although they can vary across households. This enables us to use the β_j^h as independent variables in equation (13). Within the context of this model, there is no least-squares bias because a given household's valuations of the nutrients are not affected by the levels of nutrient consumption. Consequently, the β_j^h's are assumed to be independent of the residuals in equation (13) and can be used as instrumental variables.[1]

TABLE 1. SOCIOECONOMIC VARIABLES SELECTED AS DETERMINANTS OF IMPUTED MARGINAL PRICES OF ALL FOOD FOR U. S. HOUSEHOLDS, SPRING, 1977

Variable	Definition based on 1977-78 NFCS
Income	1976 income after taxes, dollars.
Age distribution	Proportion of household members in selected stages of the life cycle: proportion less than or equal to age 2, proportion older than 2 but less than or equal to 12, proportion older than 12 but less than or equal to 19, proportion over 19 but less than 40, and proportion over 64. The omitted category was the proportion between 40 and 64.
Education of meal planner	Educational attainment of the meal planner: elementary school, high school, attended college, and college graduate. The omitted category was elementary school.
Urbanization	Residential location was represented by nonmetropolitan, suburban, or central city. The omitted category was nonmetropolitan.
Region	Region of the country was Northeast, North Central, South, or West. The omitted category was West.
Race	Race of the respondent was represented as white, black, or other. The omitted category was other.
Meal adjustment	The difference between the total number of meals served by a household and the number of family members multiplied by 21 (i.e., 21 = number of meals for 1 person for 1 week).
Food stamps	The bonus value of food stamps equaled the face value minus the amount paid.
Employment status of homemaker	Person responsible for meal planning was employed outside the home: yes = 1 and no = 0.

RESULTS

Implicit price relationships and estimated nutrient demand relationships for the United

TABLE 2. ESTIMATED IMPLICIT PRICES IN DOLLARS PER UNIT FOR NUTRITIONAL ATTRIBUTES OF ALL FOOD FOR UNITED STATES HOUSEHOLDS, SPRING, 1977[a]

	Dollars per unit	
Attributes	Implicit prices	Standard errors
Protein (gm)	.00440[b]	.00011
Fat (gm)	.00248[b]	.00004
Carbohydrates (gm)	.00021[b]	.00002
Minerals (mg)	.00012[b]	.000001
Vitamin A (I.U.)	−.00002[b]	.000001
B-complex vitamins (mg)	.02335[b]	.00015
Vitamin C (mg)	.00165[b]	.00003
R^2	.19[c]	

[a]For the pooled sample, a total of 101,649 food items were used.
[b]Significant at .01 level.
[c]R^2-like value computed as the ratio of the sum of the predicted variations, $\Sigma(\hat{P}_i - \bar{P})^2$, to the sum of the total variations, $\Sigma(P_i - \bar{P})^2$.

[1]Estimated implicit prices for attributes are stochastic in nature and these regressors violate the assumption of nonstochastic independent variables. The seriousness of this problem depends on the correlations between the stochastic independent variables and their respective error terms. These are assumed to be small.

States were estimated for protein, fat, carbohydrates, minerals, and vitamins A, B, and C. Equation (8) was estimated for each household which bought at least 20 food items. This provided a set of $\hat{\beta}_j^h$ values for each household and resulted in too many estimated equations to be analyzed individually. However, one can gain insight into the relationships involved by pooling the households and estimating equation (8) for the merged set. Thus, the per unit market prices paid by households were regressed on the nutritional attributes to obtain estimates of an average household's implicit prices.

Table 2 shows the estimated coefficients for the linear hedonic price equation for pooled households. The common attribute hedonic price equation (8) has no intercept. The interpretation is that since the foods generate varying amounts of a common set of nutrients, the price paid for a food should be distributed among the valuations of these nutrients. Therefore, a no intercept OLS program was used to estimate equation (8) for the individual households and for the pooled sample. The R^2-like value shown in Table 2 was computed using deviations about the mean price. Consequently, it should be interpreted as a measure of the explained variation with respect to the average price. An intercept regression was also computed and compared to the no intercept case. This led to the inference that the no intercept model provided a better overall fit and supports the common attribute approach.

The implicit price coefficients in Table 2 should be interpreted in terms of an average household. Positive estimates reflect positive valuations of the nutrients. Coefficients with negative signs are interpreted as the willingness to pay for the removal of an attribute from the food item. The representative household of the United States was estimated to be willing to pay \$0.0044 for an additional gram of protein. For an additional milligram of B vitamins, the representative household in the United States was estimated to be willing to pay \$0.02335.

Negative coefficients are consistent with CGCM and have been observed in other studies (Ladd and Suvannunt, p. 508). Thus, the representative household is estimated to be willing to pay an additional \$0.00002 for the removal of a 100 I.U. of vitamin A. Ladd and Suvannunt did not include this nutrient in their reported equations so no comparison can be made. Thus, presence of vitamin A may be interpreted as being associated with factors which detract from attributes such as taste, texture, and smell. They obtained a negative coefficient for vitamin C while a positive value was isolated for this study. This is assumed to reflect increased consumer awareness of the importance of this vitamin and/or a different market basket of goods purchased since the Ladd and Suvannunt study. The coefficient for minerals represents a net valuation of individual attributes which Ladd and Suvannunt found to have positive and negative valuations for the disaggregated minerals.

Another way of summarizing the individual household estimates is to present the averages across households of the $\hat{\beta}_j^h$ along with measures of variability, Table 3. Not surprisingly, the means were comparable to those obtained from the pooled sample, Table 2. Minimum implicit prices for all attributes were negative, while maximums were positive. Absolute values of coefficients of variation were largest for carbohydrates, 4.78, and were smallest for fat, .69. An implication is that consumer valuations of carbohydrates are most variable while those of fat are the least. These data indicate there is enough variation in implicit prices to permit estimation of equation (13).

Table 4 presents the estimated coefficients and standard errors of the nutrient demand relationships providing the best fit.[2] The coefficients of determination for all equations were relatively high, given cross-sectional individual household data. The percentages of variation in household demands for vitamins A and C, explained by variations of the independent variables in these equations, were not as large as the other five.

Neither of the intercept coefficients was significant which infers that a household characterized as having no income, food stamp bonus money, net meals, or members has no nutrient demand. For such a household, nutrient demands are not significantly different from zero.

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[2]Alternative equations combined income and the bonus value of food stamps, their squared values, their logs, and the reciprocal of size. Several criteria were used in evaluating the estimates of equation (13). These included parameter values, significance of the estimated coefficients, R^2, and F values. Since these equations were estimated across households, weighted least squares regressions were computed. The weights were those provided with the data to use as adjustments for the NFCS sampling (U. S. Department of Agriculture).

TABLE 3. DISTRIBUTION OF ESTIMATED IMPLICIT MARGINAL PRICES FOR NUTRITIONAL ATTRIBUTES OF ALL FOOD FOR UNITED STATES HOUSEHOLDS, SPRING, 1977[a]

Attributes	Mean	Minimum	Maximum	Coefficient of variation
Protein (gm)	.00301	−.05648	.05844	3.44
Fat (gm)	.00262	−.01248	.02184	.69
Carbohydrates (gm)	.00032	−.01805	.01222	4.78
Minerals (mg)	.00021	−.00118	.00229	1.33
Vitamin A (I.U.)	−.00002	−.00052	.00049	−2.98
B-complex vitamins (mg)	.02167	−.08982	.35821	1.07
Vitamin C (mg)	.00137	−.05224	.03986	2.64

[a]Summary data on estimated coefficients obtained from regressions for each of the 2,164 households drawn in the sampling procedure.

As expected, estimated own-implicit prices for protein, fat, minerals, vitamin B, and vitamin C had significant negative own-implicit price coefficients. Thus, as the implicit prices of these attributes increase, the quantities demanded of these attributes decrease. However, the own-implicit price of vitamin A was positive and significant. More insight can be gained through price and income elasticities. Table 5 contains estimated direct and cross-price and income elasticities based upon the significant coefficients associated with equation (13).

Since income elasticities are positive and less than one, each of the six goods is classified as normal. The relatively small values suggest that increases in income lead to proportionately smaller increases in the demands for each of the six nutrients. This is consistent with food being a necessity and a declining share of consumer expenditures being allocated to food as income increases.

The food stamp bonus elasticity measures the responsiveness of low income households to the additional income using a $150 payment. Such a household received an above average payment, but use of this amount is to reflect the impact on the very poor. The relatively large elasticities are consistent with the bonus being restricted to food items and suggest that the program has a positive effect on most nutrient consumption levels achieved by very low income households.

The first seven rows and columns of Table 5 contain the direct and cross-price elasticities. Negative own-price elasticities for protein, fat, minerals, and vitamins A, B, and C are in the inelastic range. The small absolute values suggest that the demands for these nutrients are only somewhat responsive to own marginal implicit price changes. Vitamin A had a negative own-implicit marginal price elasticity because the mean (Table 3) was negative. Thus, for this sample, small increases in this price result in a decrease in Vitamin A demand. These elasticities are consistent with the view that nutrients are necessities and as such are fairly unresponsive to implicit price changes. Cross-price elasticities were negative and small in absolute value, indicating complementary relationships, with the exception of the imputed price of fat in the vitamin C equation.

Comparing columns in Table 5 allows for an examination of marginal implicit price effects across nutrient demands. Percentage changes in the marginal implicit prices of fat and carbohydrates had the broadest impacts with respect to the number of nutrients followed closely by protein, minerals, and vitamin B. Vitamins A and C had the least price effects.

Comparing rows allows an examination of nutrient demand sensitivity in terms of marginal implicit prices and income. Protein and vitamin B quantities are most responsive to changes in implicit prices, followed by vitamin A. Demand for carbohydrates is estimated to be unaffected by these price and income variables. These results are consistent with the view that typical consumers believe their diets contained carbohydrate levels such that they were not going to change carbohydrate consumption in response to changes in implicit prices. On the other hand, consumers revealed greater willingness to change protein and vitamin A consumption levels.

The remaining variables in Table 4 are categorical. Family size was a significant positive factor in the demand for all nutrients. This result reflects the impact of household size on nutrient demand, including scale effects. An additional household member has the most pronounced effect on carbohydrates (2,053 grams per week) and the least on vitamins B and C (209 and 658 milligrams per week, respectively).

Residential location also impacted nutrient demand. Central city households consumed more protein, minerals, and vitamins A, B,

TABLE 4. NUTRITIONAL DEMAND EQUATIONS FOR SELECTED NUTRIENTS AND MINERALS: SPRING, 1977, 2,013 HOUSEHOLDS, UNITED STATES

Independent variables	Protein (g)	Fat (g)	Carbo-hydrates (g)	Minerals (mg)	Vitamin A (I.U.)	Vitamin B (mg)	Vitamin C (mg)
Intercept	−40.85	−21.70	806.92	−1,757.91	12,333.45	47.16	298.73
	(.29)[a]	(.10)	(1.58)	(.38)	(.66)	(.96)	(1.00)
Imputed prices ($.001):							
Protein	−6.16[b]	−11.33[b]	−53.124[b]	−508.76[b]	−317.98	−36.33[b]	−5.22
	(1.93)	(2.29)	(4.65)	(4.87)	(.77)	(3.30)	(.78)
Fat	.13	−35.81[b]	−74.84[b]	−488.75	−723.67	−44.00	−7.85
	(.01)	(2.02)	(1.82)	(1.30)	(.49)	(1.11)	(.33)
Carbohydrates	−8.24	6.45	−44.60	−598.06	−3,333.67	−83.14	−25.97
	(.53)	(.27)	(.80)	(1.17)	(1.65)	(1.54)	(.80)
Minerals	−158.27	−264.55	−1,499.63[b]	−18,214.41[b]	15,177.27	−67.41[b]	−113.45
	(1.49)	(1.61)	(3.95)	(5.25)	(1.10)	(1.84)	(.51)
Vitamin A	1,104.03[b]	1,241.19[b]	612.12	15,572.22	246,640.03[b]	47.61	2,283.79[b]
	(2.71)	(1.97)	(.42)	(1.17)	(4.67)	(.34)	(2.69)
Vitamin B	−2.16[b]	−2.21	−9.78[b]	−107.89[b]	−251.46[b]	−1.72[b]	−2.68
	(1.84)	(1.22)	(2.33)	(2.82)	(1.65)	(4.26)	(1.10)
Vitamin C	5.85	18.47[b]	28.56	28.27	−533.79	−11.48	−22.18[b]
	(.98)	(1.99)	(1.34)	(.14)	(.69)	(.56)	(1.78)
Income ($100)	1.29[b]	1.55[b]	.60	33.15[b]	71.19[b]	.39[b]	2.39[b]
	(5.36)	(4.15)	(.70)	(4.22)	(2.28)	(4.74)	(4.76)
Food stamp bonus	2.34[b]	2.36[b]	1.90	79.15[b]	309.15[b]	.78[b]	2.47
	(2.66)	(1.73)	(.60)	(2.75)	(2.71)	(2.57)	(1.35)
Household size	635.27[b]	846.99[b]	2,052.87[b]	21,035.78[b]	43,413.14[b]	209.07[b]	658.33[b]
	(34.61)	(29.78)	(31.27)	(35.03)	(18.23)	(33.06)	(17.20)
Location:							
City	105.72[b]	100.82	−51.27	2,577.01[b]	19,538.00[b]	30.50[b]	381.90[b]
	(2.25)	(1.38)	(.30)	(1.67)	(3.20)	(1.88)	(3.89)
Suburb	46.08[b]	153.97[b]	84.62	3,644.59[b]	14,147.26[b]	43.05[b]	314.33[b]
	(3.36)	(2.29)	(.54)	(2.56)	(2.51)	(2.88)	(3.47)
Northeast	61.84	64.12	48.94	−835.56	−2,793.41	31.47[b]	283.74[b]
	(1.14)	(.77)	(.25)	(−.47)	(.40)	(1.69)	(2.52)
North Central	52.97	53.90	78.09	−885.12	−5,872.60	26.65	−21.67
	(1.01)	(.66)	(.41)	(.51)	(.86)	(1.47)	(.20)
South	44.31	193.70[b]	382.43[b]	−317.58	−10,664.66	38.50[b]	−102.82
	(.83)	(2.33)	(1.99)	(.18)	(1.53)	(2.08)	(.92)
Net meals	580.18[b]	783.46[b]	1,658.78[b]	16,202.83[b]	36,872.78[b]	188.20[b]	608.62[b]
	(22.39)	(19.51)	(17.89)	(19.11)	(10.95)	(21.08)	(11.26)
Education:							
High school	107.82[b]	78.75	−7.14	3,028.32[b]	1,317.24	20.77	−37.28
	(1.93)	(.91)	(.04)	(1.66)	(.18)	(1.08)	(.32)
Attended college	67.59	−25.42	−197.29	3,624.27	14,113.21	−1.98	201.46
	(.99)	(.24)	(.81)	(1.62)	(1.59)	(.08)	(1.41)
College graduate	−52.87	−270.85	−239.54	-56.47	4,480.77	−43.11[b]	292.29[b]
	(.71)	(2.39)	(.90)	(.02)	(.46)	(1.67)	(1.87)
Percent age distribution:							
2 or younger	−1,274.93[b]	−1,501.94[b]	−2,269.36[b]	−26,994.97[b]	−86,541.57[b]	−435.70[b]	−828.15[b]
	(6.54)	(4.97)	(3.25)	(4.23)	(3.42)	(6.49)	(2.04)
2 through 12	−542.73[b]	−634.51[b]	−437.91	−18,279.44[b]	−48,437.36	−126.26[b]	−214.11
	(4.25)	(3.21)	(.96)	(4.38)	(2.93)	(2.87)	(.80)

Table 4. (Continued)

13 through 19	257.38[b]	263.05	1,123.08[b]	8,231.85[b]	−19,255.81	40.81	409.51
	(1.84)	(1.21)	(2.25)	(1.80)	(1.06)	(.85)	(1.41)
20 through 39	−21.59	−2.16	−149.28	−1,010.79	−15,057.23[b]	−24.50	−373.39[b]
	(.33)	(.02)	(.63)	(.47)	(1.76)	(1.08)	(2.72)
65 and older	−147.49[b]	−350.34[b]	−246.85	−1,444.19	−1,983.72	−45.82[b]	−71.68
	(2.13)	(3.27)	(1.00)	(.64)	(.22)	(1.92)	(.50)
Race:							
White	155.03	464.31[b]	356.49	11,071.22[b]	20,446.14[b]	47.52	305.40
	(1.64)	(3.16)	(1.05)	(3.57)	(1.66)	(1.46)	(1.55)
Black	267.26[b]	586.64[b]	−50.18	3,122.07	63,092.70[b]	60.50	419.71[b]
	(2.49)	(3.53)	(.13)	(1.64)	(4.54)	(1.64)	(1.88)
Homemaker employed	−2.72	−25.78	−51.30	1,118.24	−4,010.25	−5.25	−90.66
	(.07)	(.42)	(.36)	(.86)	(.78)	(.38)	(1.10)
R^2	.64	.58	.60	.64	.32	.63	.35
F	131.96	100.22	108.83	130.08	35.08	122.93	39.73

[a]Items in parentheses are t-ratios.
[b]Significant at .05 level.

TABLE 5. ESTIMATED PRICE, INCOME, AND FOOD STAMP BONUS ELASTICITIES OF SIGNIFICANT COEFFICIENTS[a]

Nutrient quantity	Implicit price: Protein	Fat	Carbohydrates	Minerals	Vitamins: A	B	C	Income	Food stamp bonus
Protein	−.009	−.013	−.027	−.024	—	−.017	—	.075	.178
Fat	—	−.034	−.033	—	—	—	—	.065	.130
Carbohydrates	—	—	—	—	—	—	—	—	—
Minerals	—	—	−.052	−.061	—	−.022	—	.061	.189
Vitamins:									
A	−.010	−.008	—	—	−.029	—	−.015	.057	.322
B	−.024	—	−.035	−.037	−.038	−.058	—	.069	.180
C	—	.009	—	—	—	—	−.012	.106	—

[a]Evaluated at the sample means, except for the food stamp bonus for which a value of $150 was used to reflect those households which received the greatest assistance.

and C than nonmetropolitan households. Suburban households consumed more of all nutrients except carbohydrates. These results supported the hypothesis that consumers in these areas had greater flexibility in choosing foods and associated diets.

Regional location had a more limited impact. Households in the Northeast consumed more vitamins B and C, while households in the South consumed more fat, carbohydrates, and vitamin B. This suggested that residential life-styles of the urban/rural dimension had greater impacts than regional location.

The meal adjustment variable incorporated differences in eating habits among all households by combining all family meals consumed in the home with guest meals and subtracting meals eaten away from home or skipped by members of the household. An increase in total or guest meals increased household demand for each respective nutrient. An increase in skipped or away meals decreased household demand for each respective nutrient. While all nutrient levels were affected, the most pronounced effect was for carbohydrates (1,659 grams per week) and the smallest was for vitamin B (188 milligrams per week).

Households in which the meal planner had a high school education consumed more protein (108 grams per week) and minerals (3,028 grams per week), and households in which the homemaker had graduated from college demanded less vitamin B (43 milligrams per week) and more vitamin C (292 milligrams per week). The absence of a consistent pattern in which consumption of nutrients thought to have positive effects on health increased and those which have a negative effect decreased as the level of education increased suggested that nutritional awareness does not increase with education.

The age distribution of the household was an important determinant. Households with very young children were associated with lower levels of consumption of all nutrients. This was also true for households with young children with the exceptions of carbohydrates and vitamins A and C. The percent of teenagers in a household had positive effects on protein, carbohydrates, and mineral consumption, while the proportion of young adults in a household had negative effects on vitamins A and C consumption. Lower consumption of protein, fat, and vitamin B was associated with a higher percent elderly in a household.

White households consumed more fat, minerals, and vitamin A than "other" race households. Black households demanded significantly more protein, fat, and vitamins A and C than "other" race households. These results suggest that diets and thus nutrient intake vary among racial groups.

SUMMARY AND CONCLUSIONS

A new consumer goods characteristics model has been presented in which market goods generate a common set of attributes without producing unique attributes. This form of the characteristics model is well-suited for food demand because the nutrients contained in the food items are found in more than a single commodity. Two equations were estimated using household-level cross-sectional data. The hedonic price equation was estimated within households. The nutritional demand equations were estimated across households.

Estimation of the hedonic price equation confirmed the characteristics model approach. Measures of overall fit led to an inference of significant relationships which supports the assumption that the prices consumers pay for food reflect consumers' valuation of the common nutrients contained in food. With the exception of vitamin A, all the nutrients have significant positive coefficients. This suggests that consumers are willing to pay more for food as the nutritional content increases. It also suggests that the promotion of food can be in terms of the nutritional composition of commodities and is consistent with the recent effectiveness of the generic advertising of foods which include nutritional emphases.

The estimated nutrient demand equations also support the characteristics model. Own-price elasticities for the implicit valuations of the nutrients suggest inelastic demands for each of the nutrients. The presence of very few cross-price elasticities means that little substitution occurs across nutrients. This is consistent with each nutrient making a specific contribution to personal health. Income elasticities were positive and small. Food stamp bonus elasticities were at least twice as large as income elasticities. These elasticities indicate that the food stamp program has significant impacts on the nutrient intake of consumers. The results are consistent with food as a necessity and with a relatively high standard of living in the United States.

Household composition and location had significant impacts on nutrient demand. The implication is that public policies and the promotion of foods should incorporate these features. Projected declines in household size create a market for foods packaged in smaller nutritional bundles. Nutritional levels of rural poor households were found to be lower than central city and suburban households. Regional effects were more limited than the urban-rural distinction and suggested that regional variations in nutrient levels were less of a concern. An increasingly older population is projected to result in lower nutrient demand levels. The absence of a consistent pattern of education-related coefficients means that nutritional information and promotion should be directed at all educational levels.

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