1985

Some Evidence of the Demand for Food Variety:
A Case Study of Food Items

Jonq-Ying Lee, J. S. Shonkwiler and Mark G. Brown*

Diet

AAEA paper presented at its annual meetings.
Ames, Iowa, Aug 4-7, 1985

*Jonq-Ying Lee is a Research Economist, Economic Research Department, Florida Department of Citrus; J. S. Shonkwiler is an Associate Professor, Department of Food and Resource Economics, University of Florida; and Mark G. Brown is a Research Economist, Economic Research Department, Florida Department of Citrus.

Some Evidence of the Demand for Food Variety:
A Case Study of Food Items

Abstract

The paper examines the corner solution in consumer demand analysis focusing on the relationship between the number of food commodities purchased and total food expenditures. Empirical results provide evidence that the number of commodities purchased both in aggregate and in specific commodity groups increases with total food expenditures, and indirectly supports the assertion that more variety is associated with greater utility.

Keywords: Demand, Food Variety, Tobit.

Some Evidence of the Demand for Food Variety:
A Case Study of Food Items

The analysis of the demand for products of different ingredients, flavors, colors or varieties is an important topic in economics. This question has been considered intermittently in the literature on demand for quality, receiving particular attention in recent years. Various models have been advanced to describe the relation between quality and demand. In particular, goods with different quality characteristics have been treated alternatively as separate commodities (Lancaster, 1966, 1971), and as part of the same general commodity (Houthakker, 1952; Theil, 1952).

The usual treatment of consumer demand theory assumes the existence of demand equations with the property that positive quantities of all commodities are consumed. However, some attention has been given to the corner solution and the number of commodities purchased. In particular, Prais (p. 88) has asserted that within aggregates of similar but differentiated goods treated as composite commodities the number of such goods expands with expenditure. In another earlier study, Houthakker (1953) used a quadratic utility function to examine the order in which commodities enter and leave the budget. However, the properties of the purchased set were not explored. More recently, Jackson demonstrated that under the assumption of an additive preference function, the number of commodities purchased is a monotonically increasing function of income, while Theil and Finke (1983) have found evidence that variety in consumption is positively related to income, based on the entropy of budget shares.

Thousands of new products are introduced to consumers each year. In order to develop these new products successfully, it is important to have knowledge about the demand for variety within certain narrowly defined commodity groups. The purposes of this study are (1) to review the relevant economic theory about the demand for variety, and (2) to use food items as an example to show the relationship between the demand for food variety and income.

Demand for Variety

Following Jackson consider a utility function $u(q)$ defined for any vector of quantities q in some set of n commodities and let

$$u(q) = u(q_1,\ldots q_n) \qquad (1)$$

where $u(q)$ is to be maximized subject to

$$\sum_j p_j q_j = m \qquad (2)$$

$$q_j \geq 0 \qquad (3)$$

where p_j is the price for jth commodity and m is income. One commodity may be savings.

When $u(q)$ is maximized, the following Kuhn-Tucker conditions are satisfied

$$\partial u/\partial q_j - \lambda p_j = 0 \qquad \text{if } j \in S \qquad (4)$$

$$q_j \geq 0$$

and,

$$\partial u/\partial q_j - \lambda p_j < 0 \qquad \text{if } j \in \overline{S} \qquad (5)$$

$$q_j = 0$$

where λ is the Lagrangian multiplier, S is the set of commodities purchased, and $\overline{S}$ is the set of commodities not purchased or the complement of S, i.e., $I = S \cup \overline{S}$, is the set of all commodities considered in (1). The conditions (2) through (5) can be solved to give the Marshallian demand functions

$$q_j = q_j(P,\ m). \qquad (6)$$

where P is the vector of prices of the n commodities and $q_j(P,m) = 0$ if expression (5) holds.

Let $S(m) = \{j \mid q_j(P,m) > 0\}$ be the set of all commodities in the purchased set S for given P. Subsequent discussion relates to the set S(m).

Ignoring the change in the number of commodities purchased, the consumer's reaction to a change in his or her money income m, prices being held constant, can be shown to be (Theil, 1975)

$$Q_m = \lambda_m U^{-1} P, \qquad (7)$$

and,

$$P'Q_m = 1, \qquad (8)$$

where $Q'_m = [\partial q_1/\partial m, \ldots, \partial q_n/\partial m]$; $\lambda_m = \partial\lambda/\partial m$; and U is the hessian for the utility maximization problem, with its element $U_{ij} = \partial^2 u/\partial q_i \partial q_j$, for i, j = 1,..., n.

What equation (7) says is that convexity of the indifference curves is insufficiently strong to rule out the possibility of inferior goods. That is, it is possible to have $\partial q_j/\partial m < 0$, depending on the sign of $\Sigma_i (u^{ji}) p_i$. It is not possible, however, for all q_j's to be inferior, which is indicated by equation (8). Note that inferiority is of necessity a local concept. Goods can not be inferior over the whole range of consumption, or else they would never be consumed in a positive amount in the first place (Silberberg, pp. 240-1).

Equation (8) can be rewritten as

$$\Sigma_j w_j E_{jm} = 1 \qquad (9)$$

where $w_j = p_j q_j/m$ and E_{jm} is the income elasticity for commodity j. Equation (9) states that the weighted average of all income elasticities, with the corresponding budget shares as weights, is equal to one. Those budget shares are obviously positive and add up to one. When income increases and all prices remain unchanged, the shares of luxuries ($\varepsilon_{jm} > 1$) go up while those of necessities ($\varepsilon_{jm} < 1$) go down (a given proportionate income increase has a larger (smaller) proportionate effect on the numerator $p_j q_j$ in w_j when the income elasticity is larger (smaller) than one). With positive income elasticities the expenditures on luxuries and necessities increase. Alternatively, with negative income elasticities the expenditures on inferior foods decrease with income. Therefore, a change in real income, in general, results in a reallocation of consumer's resources even if prices do not change or if they change in the same proportion.

In addition, when income increases, some of the commodities in S may be purchased due to the reallocation of consumer's resources. Therefore, the number of commodities purchased changes with income, i.e., the cardinality of S(m) changes with income.

Equations (4), (5), (7), and (8) define the conditions for commodities to be purchased, but they do not provide the direction of changes in the number of commodities to be purchased as income changes, i.e., the number of commodities purchased may increase, be invariant, or decrease with income.

Some Empirical Evidence

This study examines food consumption data from the Nationwide Food Consumption Survey (NFCS) conducted in 1977-78 by the U.S. Department of Agriculture. Since information on the purchases of non-food items is not available and more than 25% of the households in the sample did not report their household incomes, it is assumed that the utility function (1) is weakly separable, such that

$$u(q) = f(u_f(q^f), u_{nf}(q^{nf})) \tag{10}$$

where f(.) is some increasing function and u_f and u_{nf} are the subutility functions associated with food and non-food items, respectively; q^f is a vector of quantities of food items and q^{nf} a vector of quantities of non-food items. The maximization of utility in (10) implies that u_f and u_{nf} are each maximized subject to the expenditures on food and non-food items. The expenditures on food items are the outcome of maximizing $u_f(q^f)$ subject to $p^{f\prime}q^f = m^f$, the total expenditures on food, so that

$$q_i = q_{fi}(p^f, m^f) \qquad i \in \text{food} \tag{11}$$

for the Marshallian subgroup demands. The arguments developed in the previous section still apply to this subutility maximization problem.

In Table 1, data are provided on three-person households in eight food expenditure groups. These data show that the average number of food items purchased increases as food expenditures increase. Note that the households in food expenditure group 8 purchased on average at least 37 food items not in the basket of food purchased by households in group 1. However, the real difference between them is greater than this. Some food items may be inferior goods, or be complementary to inferior goods. These food items are unlikely to be included in the budget of the high income households so that baskets of food items consumed by the two groups are even more differentiated.

The average number of food items purchased in selected food groups is shown in Table 2. Note that the average number of food items purchased in most of the food groups increases as food expenditures increase.

The information provided by the NFCS permits examination of the hypothesis that the number of commodities purchased changes with income. In this study, the functional relationship[1] used to examine the relationship between variety and the level of food expenditure is

$$S_{ih} = a_{0i} + a_{1i} \log(m_h^f) + e_{ih} \qquad (12)$$

where S_{ih} is the number of food items of category i purchased by household h, m_h^f is the food expenditures of household h, a_{0i} and a_{1i} are parameters to be estimated, and the e_{ih}'s are disturbance terms, independently and normally distributed with mean zero and variance σ_i^2. Since S_{ih} is zero for some food categories purchased by a given household, the Tobit estimation technique was employed. Table 3 gives the main results.[2]

Note that all estimated slope coefficients are two times larger than their corresponding asymptotic standard errors, supporting the hypothesis that food expenditure is an explanatory variable for variety in food consumption. Futhermore, for every food group the estimated coefficient on income is positive. This finding is consistent with studies of Theil (1952) and Jackson who analyze more aggregative groups of commodities. In order to compute income elasticities it is necessary to calculate how the number of commodities purchased reacts to changes in income. There are three alternative views as to how this is done in the context of a limited dependent variable model. Maddala (pp. 158-60) demonstrated when one defines the model in (12) in a Tobit model framework, i.e.,

$$S_{ih} = a_{0i} + a_{1i} \log(m_h^f) + e_{ih} \quad \text{if RHS} > 0$$
$$= 0 \quad \text{otherwise;} \qquad (13)$$

and considers the non-zero observations S_{ih}, then

$$E(S_{ih} \mid S_{ih} > 0) = a_{0i} + a_{1i} \log(m_h^f) + \sigma_i \phi(z_{ih})/\Phi(z_{ih})$$

where ϕ and Φ are the density function and distribution function of the standard normal evaluated at $z_{ih} = (a_{0i} + a_{1i} \log(m_h^f))/\sigma_i$; and

$$\partial E(S_{ih} \mid S_{ih} > 0)/\partial m_h^f$$
$$= a_{1i}(1 - z_{ih}\phi(z_{ih})/\Phi(z_{ih}) - (\phi(z_{ih})/\Phi(z_{ih}))^2)/m_h^f. \qquad (14)$$

Instead of using only the non-zero observations on S_{ih}, if one uses all the observations,[3] then

$$E(S_{ih}) = \Phi(z_{ih})\ (a_{0i} + a_{1i} \log(m_h^f)) + \sigma_i \phi(z_{ih}),$$

and,

$$\partial E(S_{ih})/\partial m_h^f = \Phi(z_{ih}) a_{1i}/m_h^f. \qquad (15)$$

If one defines the model in (13) in a latent variable framework, i.e.,

$$S_{ih}^* = a_{0i} + a_{1i} \log(m_h^f) + e_{ih},\ E(e_{ih}) = 0;$$

where $S_{ih} = S_{ih}^*$ if $S_{ih}^* > 0$

$= 0$ otherwise,

then $E(S_{ih}^*) = a_{0i} + a_{1i} \log(m_h^f)$, and,

$$\partial E(S_{ih}^*)/\partial m_h^f = a_{1i}/m_h^f. \qquad (16)$$

Equations (14) through (16) were used to derive the food expenditure elasticities of demand for variety. The results are presented in Table 4 (all elasticities are calculated at the sample means of the S_{ih}'s). Note that the estimated food expenditure elasticities of demand for variety from equations (14) and (15) indicate that the demand for the variety of fresh fruit and vegetables, poultry and seafood, beverages, nuts and condiments are more responsive to food expenditures than the demands for the variety in other food items. From the point of view of those in the food industry, these results might suggest that product development focus on the food types most responsive to overall food expenditures, considering the general rise in income and food expenditure in the U.S. in recent years.

Concluding Remarks

The approach used in this study is different from that discussed by Hanemann (1982, 1984), where quality measurements are embedded in the utility function and a positive relationship is assumed between quality and the utility level. If one assumes that more variety represents higher quality of the commodities purchased by a consumer, then the theory reviewed in the present study is incomplete with respect to the relationship between variety and utility level. However, the results found in this study provided evidence of the increase in the variety of food items purchased with food expenditures and indirectly provides support for the assertion that more variety is associated with greater utility.

Footnotes

[1]The cardinality of S should be a function of P and m. Since price information was not available for all households in the sample, it was deleted from the model.

[2]Other functional forms were also tried, i.e.,

$$S_{ih} = a_{0i} + a_{1i}\, m_h^f + e_{ih}, \text{ and}$$

$$S_{ih} = a_{0i} + a_{1i}\, \log(m_h^f)/P_h + e_{ih};$$

where $P_h = \sum_i w_i \log(p_{ih})$ is the Stone price index.

[3]Equation (15) is the same as equation (2) in McDonald and Moffitt (p. 318).

Table 1. Average number of food items purchased by household food expenditure group -- three-person households

Food Expenditure Group Code	Weekly Food Expenditure Group Dollars	Number of Households	Average Food Expenditures Dollars	Avg. No. of Food Items Purchased Per Household
1	Less than 24.50	261	19.13	29.26
2	24.50 - 31.99	393	28.65	39.23
3	32.00 - 37.49	344	34.71	45.42
4	37.50 - 42.69	310	40.28	47.95
5	42.70 - 51.99	461	47.07	52.29
6	52.00 - 56.99	198	54.16	56.73
7	57.00 - 72.49	395	63.27	57.94
8	72.50 and above	264	91.25	66.72
	All Households	2,626	46.53	49.27

Table 2. Average number of food items purchased by food category and by food expenditure group -- three-person households

Food Category	Food Expenditure Group Code								All Households Average
	1	2	3	4	5	6	7	8	
Milk	2.57	3.33	3.90	4.07	4.55	4.67	5.01	5.73	4.2277
Fats & Oils	2.03	2.73	3.21	3.22	3.40	3.72	3.77	3.90	3.2475
Flour & Cereal	2.87	3.66	4.33	4.46	4.64	4.67	5.06	5.40	4.3975
Bakery	2.93	3.79	4.25	4.42	4.88	5.37	5.64	6.32	4.6831
Meat	3.39	4.52	5.12	5.56	5.94	6.52	6.68	7.81	5.6645
Poultry & Seafood	0.99	1.27	1.47	1.64	1.78	1.91	2.03	2.63	1.7010
Eggs	0.91	0.95	0.98	0.98	1.01	0.99	1.02	1.04	0.9859
Sugar & Sweets	1.97	2.68	3.03	3.11	3.40	3.85	3.76	4.25	3.2418
Potatoes	0.99	1.25	1.49	1.48	1.55	1.72	1.73	1.75	1.4939
Fresh Vegetables	2.25	3.60	4.14	4.53	5.26	5.49	5.90	6.86	4.7536
Fresh Fruit	1.14	1.84	2.06	2.34	2.77	2.58	2.73	3.72	2.3994
Canned Fruit & Veg.	1.82	2.36	2.90	2.97	3.10	3.53	3.27	3.82	2.9520
Frozen Fruit & Veg.	0.33	0.50	0.67	0.72	0.74	0.72	0.80	0.91	0.6755
Veg. & Fruit Juices	0.86	1.07	1.19	1.40	1.41	1.45	1.65	1.75	1.3457
Dried Fruit & Veg.	0.25	0.40	0.34	0.36	0.48	0.39	0.45	0.60	0.4135
Beverages	1.63	2.14	2.61	2.89	3.33	3.85	3.91	4.64	3.0963
Soup, Sauces, Gravies	0.68	0.80	1.04	1.01	1.05	1.28	1.10	1.40	1.0289
Nut, Condiments	0.89	1.54	1.76	1.96	2.11	2.62	2.61	3.06	2.0479
Mixtures, Baby Mix.	0.75	0.80	0.93	0.82	0.89	1.39	0.86	1.14	0.9169
Total	29.26	39.23	45.42	47.94	52.29	56.73	57.97	66.72	49.2725

Table 3. Tobit estimates for semi-log variety choice models -- three-person households

Food Category	Intercept	Logarithmic Income	σ^2	Non-buying HHS
Milk	-12.7206 (0.6692)[a]	2.0286 (0.0802)	3.7227	11
Fats & Oils	-7.6620 (0.4735)	1.3015 (0.0567)	2.0427	65
Flour & Cereal	-11.0103 (0.6765)	1.8253 (0.0812)	5.4443	66
Bakery	-14.0443 (0.7897)	2.2394 (0.0946)	5.4925	15
Meat	-17.6352 (0.6544)	2.7857 (0.0783)	4.2611	24
Poultry & Seafood	-9.1087 (0.4955)	1.2620 (0.0593)	2.1677	412
Eggs	0.7613 (0.0959)	0.0307 (0.0113)	0.0353	102
Sugar & Sweets	-10.7512 (0.6376)	1.6561 (0.0765)	4.2030	99
Potatoes	-3.3840 (0.3523)	0.5809 (0.0421)	0.8622	257
Fresh Vegetables	-28.9371 (0.8429)	3.9617 (0.1018)	10.1374	149
Fresh Fruit	-15.9669 (0.6186)	2.1201 (0.0740)	4.9780	381
Canned Fruit & Veg.	-16.9015 (0.8113)	2.1061 (0.0967)	15.9771	452
Frozen Fruit & Veg.	-12.6456 (0.9788)	1.1405 (0.1162)	9.9271	1,651
Veg. & Fruit Juices	-6.8166 (0.4944)	0.9278 (0.0591)	2.2649	594
Dried Fruit & Veg.	-7.1254 (0.7703)	0.6237 (0.0916)	4.5457	1,789
Beverages	-17.6835 (0.6734)	2.4516 (0.0809)	4.6800	175
Soup, Sauces, Gravies	-8.2174 (0.6985)	0.8674 (0.0832)	6.1907	1,172
Nuts, Condiments	-16.8660 (0.6456)	2.1482 (0.0770)	5.6273	529
Mixtures, Baby Mix.	-10.6515 (1.1959)	0.6826 (0.1426)	20.5442	1,513
All Food Items[b]	-143.3892 (4.4805)	23.0782 (0.5359)		0

[a]Numbers in parentheses are standard errors of the Tobit estimates.

[b]OLS estimates with R^2 = .4141 and F - ratio = 1,854.37.

Table 4. Estimated income elasticities

Food Categories	Non-zero Observations	All Observations	Latent Variable Model
	Equation (14)	Equation (15)	Equation (16)
Milk	0.4315	0.4678	0.4798
Fats & Oils	0.3653	0.3928	0.4008
Flour & Cereal	0.3483	0.3968	0.4151
Bakery	0.4154	0.4615	0.4782
Meat	0.4679	0.4861	0.4918
Poultry & Seafood	0.4609	0.6068	0.7419
Eggs	0.0311	0.0311	0.0311
Sugar & Sweets	0.3911	0.4703	0.5108
Potatoes	0.3065	0.3638	0.3889
Fresh Vegetables	0.5904	0.7276	0.8334
Fresh Fruit	0.5019	0.6750	0.8836
Canned Fruit & Veg.	0.2891	0.4039	0.7134
Frozen Fruit & Veg.	0.3396	0.2766	1.6883
Veg. & Fruit Juices	0.3594	0.4995	0.6895
Dried Fruit & Veg.	0.3197	0.2808	1.5084
Beverages	0.6262	0.7331	0.7918
Soup, Sauces, Gravies	0.2427	0.2944	0.8431
Nuts, Condiments	0.5034	0.6957	1.0490
Mixtures, Baby Mix.	0.1405	0.1026	0.7444
All Food Items[a]	------	------	0.4684

[a]OLS estimate.

References

Hanemann, W.M. (1952) "Quality and Demand Analysis," in New Directions in Econometric Modeling and Forecasting in U.S. Agriculture, ed. G.C. Rausser, New York: North-Holland.

Hanemann, W.M. (1984) "Discrete/Continuous Models of Consumer Demand," Econometrica, 52: 541-61.

Houthakker, H.S. (1952) "Compensated Changes in Quantities and Qualities Consumed," Rev. Econ. Studies, 19: 155-64.

Houthakker, H.S. (1953) "La Forme des Courbes d'Engel," Cahiers du Seminaire d'Econometric, 2: 59-66.

Jackson, L.F. (1984) "Hierarchic Demand and the Engel Curve for Variety," The Rev. Econ. and Stat., LXVI: 8-15.

McDonald, J.F. and R.A. Moffitt (1980) "The Uses of Tobit Analysis," The Rev. Econ. and Stat., LX11: 318-21.

Maddala, G.S. (1983) Limited-Dependent and Qualitative Variables in Econometrics, New York: Cambridge University Press.

Prais, S.J. (1953) "Non-linear Estimates of the Engel Curve," Rev. Econ. Studies, 20: 87-104.

Silberberg, E. (1978) The Structure of Economics--A Mathematical Analysis, New York: McGraw-Hill, Chapter 8.

Theil, H. (1952) "Qualities, Prices and Budget Inquiries," Rev. Econ. Studies, 19: 129-47.

Theil, H. (1975) Theory and Measurement of Consumer Demand, Vol. 1, New York: North-Holland, Chapter 1.

Theil, H. and R. Finke (1983) "The Consumer's Demand for Diversity," European Economic Review, 23: 395-400.