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by Elena Lopez
and Rigoberto A. Lopez

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**Demand for Differentiated Milk Products:
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Elena Lopez and Rigoberto A. Lopez*

*Associate Professor at the University of Alcalá, Madrid (Spain) and Professor at the University of Connecticut, respectively. The authors are grateful to Benaissa Chidmi for helpful advice regarding the performance of the model. Financial support was provided by the University of Alcalá and by the Food Marketing Center at the University of Connecticut.

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Abstract: This article uses a discrete choice, random coefficients logit model for analyzing consumer behavior and retail price competition in the Boston fluid milk market. The problems of product dimensionality and consumer heterogeneity implied by imperfect substitution in markets with differentiated products were solved by applying the model of Berry, Levinhson and Pakes (1995). Empirical results show that private label milks have the highest markups in spite of lower prices, which may explain their rapid expansion, while low-fat and specialty milks such as organic and lactose-free are preferred by high income groups with no children.

Key words: Demand analysis, random coefficients model, milk, consumer behavior, retail pricing, markups, competition.

JEL Classification: D12, D40, L11, L81

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Introduction

In the past decade the profile of milk consumption in U.S. supermarkets has undergone rapid change. Health considerations have triggered increased demand for lower fat-content types of milk as well as for specialty products, such as organic and lactose-free milk, resulting in dozens of choices at a single supermarket. Understanding the demand for such differentiated products constitutes a cornerstone for further analysis of price competition.

Demand for differentiated products raises the issue of dimensionality as the number of alternative products increases the number of parameters exponentially making estimation intractable. The classical methods of demand such as the Linear Expenditure model (Stone, 1954), the Rotterdam model (Theil, 1965), and the Almost Ideal Demand System (Deaton and Muelbauer, 1980) address the dimensionality problem by considering only a reduced number of categories. Spence (1976) and Dixit and Stiglitz (1977) solve the problem by proposing a constant elasticity of substitution utility function but impose the restriction that all cross-price elasticities are equal. Another approach has been to group the products into smaller categories and use a flexible form to estimate demand within each category (Hausman, Leonard and Zona, 1994), introducing the difficulty of division across categories.

Demand for differentiated products also raises the issue of consumer heterogeneity. The models noted above do not address this issue since demand is modeled using a “representative” consumer, per capita demand, or highly restrictive utility functions. One of the most influential of the last wave of demand models is the one by Berry, Levinsohn and Pakes (1995; henceforth BLP), which solves the problems of dimensionality, consumer heterogeneity, and endogneity of product prices. This model also offers the advantage of resolving the restrictive and implausible substitution patterns implied by the use of classical discrete choice models such as the logit or nested logit. In addition to the original BLP application to the automobile industry, the BLP model has also been applied to breakfast cereals (Nevo, 2001; Chidmi and Lopez, 2007), prepared frozen meals (Mojudszka and Caswell, 2001), cheese (Kim, 2004), beer (Hellerstein, 2004) and yogurt (Villas-Boas, 2007).

In this paper, we apply the BLP model to 22 competing varieties of fluid milk sold at the four leading supermarket chains in Boston. We use four-weekly data from 1998 to 2000, complemented with data on consumer demographics (income and number of children under 15 living in the household) to estimate the individual consumer taste parameters for alternative milk characteristics. These parameters allow us to estimate own- and cross-price elasticities, marginal costs, and retail markups at the product brand level and for distinct groups of consumers to provide a detailed picture of consumer behavior and price competition in this market.

The Model

Following Berry, Levinsohn and Pakes (1995), we assume that a consumer chooses to buy one unit of the product that generates the highest utility among all the options available in terms of the product's characteristics as well as the consumer's personal characteristics. The indirect utility function can thus be written as

(1) $U_{ij} = \alpha_i p_j + \beta_i x_j + \varepsilon_{ij}$ $\quad i = 1,...,n$ consumers; and $j = 1, \ldots, J$ products,

where p_j is the price of product j, x_j is the vector of observed product characteristics, α_i and β_i are the consumer-specific parameters (also called 'taste parameters') and ε_{ij} is a stochastic term. As individual taste parameters change with consumer demographics and other unobserved variables, these parameters are expressed as

$\alpha_i = \alpha + \lambda D_i + \omega V_i$ *and* $\beta_i = \beta + \delta D_i + \gamma V_i$, where D_i and V_i represent, respectively, the sets of observed and unobserved consumer characteristics with probability density functions *h(D)* and *g(V)*, assumed to have a normal distribution N(0,1), and $\alpha, \beta, \lambda, \delta, \omega, and\ \gamma$ are fixed parameters. Substituting D_i and V_i back into (1) yields

(2) $U_{ij} = \rho_j + \mu_{ij} + \varepsilon_{ij}$,

where $\rho_j = \alpha p_j + \beta\ x_j$ is the mean utility level of product *j*, linear in product characteristics and common to all consumers, and $\mu_{ij} = \lambda D_i p_j + \delta D_i x_j + \omega V_i p_j + \gamma V_i x_j$ represents the deviations from the mean utility due to the differences in consumer characteristics.

We define an outside good to allow for the possibility that the consumer does not choose any of the *J* products defined above. The outside good also helps us define the size of the market and, thereby, define market shares. Following standard practice, the price of the outside good is set to be independent of the prices of the J varieties included in the choice set and its utility is normalized to zero. As consumers purchase a unit of the product that maximizes their utility, the market share of each product equals the probability that that specific product is chosen, which is given by

(3) $S_j(p, x, \Theta) = \int I\{(D_i, V_i, \varepsilon_{ij}) : U_{ij} \geq U_{ik} \forall\, k = 0,...J\} dH(D)dG(V)dF(\varepsilon)$,

where $\Theta = (\alpha, \beta, \lambda, \delta, \omega, \gamma)$ is the vector of consumer taste parameters, $k = 0$ denotes the outside good, and *H(D)*, *G(V)* and $F(\varepsilon)$ are cumulative density functions for the indicated variables, which are assumed to be independent from each other.

From (3), the own- and cross-price elasticities are:

(4) $$\eta_{jk} = \frac{\partial S_j}{\partial p_k}\frac{p_k}{S_j} = \begin{cases} \dfrac{P_i}{\eta_j}\int \alpha_i S_{ij}\ (1-\alpha_{ij})\alpha H(D)\alpha G(v), for\ j=k \\ \dfrac{P_\kappa}{S_j}\int \alpha_i S_{ij}\ S_{ik}\,\alpha H(D)dG(v), otherwise. \end{cases}$$

For the supply side, assume that supermarkets take the wholesale prices as given and that they choose the range of prices for the *J* differentiated products in order to maximize total profits from milk. That is, a retailer maximizes

$$(5)\ \Pi = \Sigma_j (p_j - c_j) S_j(p) M,$$

where p_j is product *j*'s retail price, c_j is the retailer's marginal cost, S_j is the market share, *p* is the vector of all retail prices, and *M* is market size. Assuming a Bertrand-Nash equilibrium, the first-order conditions are:

$$(6)\ S_j + \sum_k (p_k - c_k) \frac{\partial S_k}{\partial p_j} = 0 .$$

This yields a set of J equations which can be rewritten in vector notation as

$$(7)\ p - c = -\Omega^{-1} S(p)$$

where *p, c* and *S* are the price, marginal cost and market share vectors and Ω is a block diagonal matrix of the derivatives of market shares with respect to prices. Equation (7) can be instrumental in calculating the marginal cost (since prices are observed) as well as the gross price-cost margins at the brand level. The Lerner indices of oligopoly power at the brand level can be simply obtained as $L_j=(p_j-c_j)/p_j$.

Data and Estimation

The data consist of two sets: milk sales and consumer characteristics. The milk sales data came from the Information Resources Incorporated database provided by the Food Marketing Center at the University of Connecticut. The sample consists of milk sold by the four leading supermarket chains in the greater Boston area (including Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, and Worcester counties) during 27 four-week periods from July 1998 to July 2000. These supermarket chains account for approximately 70% of the grocery market share in the Boston area.

Product characteristics include: brand name (with private label or store brand considered as one brand name, Hood, Garelick, Morningstar, McNeil, Organic Cow of Vermont), fat content (0, 1, 2% and whole milk, which is 3.25% fat), lactose content, and organic milk. Other characteristics such as calories, alcohol, and sugar contents, typically observed in different amounts in other products, are homogeneous across types of milk with the same fat contents, and thus, are not considered here. After dropping all milk with less than 0.5% market share (of milk sold by the four supermarket chains), the sampling procedure generated 22 “products” as described by these four characteristics.

Retail prices were computed by dividing the dollar sales of each product by volume sold. Market size is measured by total milk consumed in the Boston area; hence the outside good is total milk sold that is either not part of the 22 milk products in the sample or sold in other retail outlets. Market shares for each product are computed with respect to the potential market for milk. According to the USDA/ERS Livestock,Dairy and Poultry Outlook, U.S. per capita consumption of fluid milk amounted to 0.93 8-ounce servings of fluid milk per day, or an average of 1.63 gallons of fluid milk per person during period of the study. As a result, the volume of milk included in that data set represents approximately 51% of the potential market, which includes milk not only bought at grocery stores but also gas stations and convenience stores.

Consumer characteristics for the Boston market were obtained from the Current Population Survey (CPS) database available from the U.S. Bureau of the Census. Observable characteristics include household income and the number of persons under the age of 15 living in the same household. For each of the 27 time periods of four weeks, 250 observations on income and number of persons under 15 were drawn to match milk purchases. Average household income for the selected survey population is

U.S. $56,400, while each household contains an average of 0.51 children under the age of 15. These values are very close to those observed for the total population in Boston. Unobservable characteristics were generated randomly from a normal distribution with zero mean and standard deviation of one, as done by Chidmi and Lopez (2007) and Nevo (2001).

Each time period was treated as a market consisting of 22 products and 250 consumers. Stacking these markets generated 594 products (22 x 27) and 6,750 (250 x 27) consumer observations. Once all the data were operational, the integral in (3) was solved numerically following Berry (1994), modifying the algorithm of Nevo (2000). The demand parameters for the mean utility and interactions of product and consumer characteristics were computed by minimizing the distance between predicted and observed market shares, interacting the deviations with a set of instruments using the Generalized Method of Moments (GMM).

The instrumental variables used in the GMM estimation addresses the problem of the potential endogeneity of product prices. Following Villas-Boas (2007), the interactions of 22 brand dummies with input prices (price of raw milk, wages, price of electricity, price of gas, and interest rates) and with the average size of milk containers are used, resulting in 111 instrumental variables. Energy prices and labor costs came from the U.S. Department of Energy and the U.S. Department of Labor websites and are specific for the Boston area. The interest rates used are the monthly Moody AAA rates from Economagic. The price of raw milk adjusted for butterfat content was provided by the Food Marketing Policy Center. The average size of milk containers came from the milk sales dataset (Information Resources, Inc.) provided by the Food Marketing Policy Center.

Once the demand results were obtained, the estimated parameters were used to calculate price elasticities, marginal costs and oligopoly Lerner indexes at the specific product level. The results are presented in the following section.

Empirical Results

Table 1 presents the estimated taste parameters for the mean utility and deviations from the mean depending on consumer characteristics. The taste performance for each product characteristic can also be represented by the following equations:

(11) Price $= -0.87 + 0.19D_I - 0.25D_K - 0.25V_i$

(12) Fat content $= 0.13 - 0.70D_I + 0.14D_K - 0.07V_i$

(13) Organic $= -0.87 + 0.19D_I - 0.25D_\mathrm{K} - 0.25V_i$

(14) Lactose-free $= -3.72 + 0.48D_I - 0.63D_K - 0.49V_{i,}$

where D_I, D_K and V_i are consumer income, the number of children under 15 years of age, and unobserved consumer characteristics, respectively.

The estimated parameters of the mean utility show an expected negative reaction to price increases, which diminishes with higher household income and a lower number of children. In general, there seems to be an overall preference for conventional milk, i.e., non-organic, non-lactose-free, and containing some milk fat, that is more pronounced in households with children. On the other hand, the higher the income level, the greater the preference for specialty milk types, especially for organic, lactose-free and above all for milks containing lower levels of fat.

Figure 1 compares consumer valuations of milk fat content valuations by income quartiles. The mean value of the fat parameter decreases consistently as income increases. The mean value of the fat parameter of the lowest income quartile is 0.76, while those in the second, third and highest quartiles have means of 0.24, -0.07 and

-0.38, respectively. Thus, consumers with higher income then tend to purchase milk with lower fat content.

Figure 2 compares milk fat content valuations by number of children under 15 in the household. The mean value of the fat parameter consistently increases as the number of children in the household increases. The estimated mean value of the taste parameter for the groups of consumers with zero, one, two, and three children under 15 are 0.13, 0.27, 0.42 and 0.56, respectively, which indicates that the preference for higher-fat milk increases as the number of children in the household increases.

In total, 484 own-and cross-price elasticities were computed (22x22). Table 2 presents a selected group of price elasticities for eight milk products (64 in total), involving 1% fat and whole milk as the most popular fat content choices.

As expected, all the own-price elasticities are negative. The own-price elasticities for private label conventional milk are about half (more price inelastic) as those for the brand of organic milk and roughly only about one-fourth of the own-price elasticity for lactose-free brands. This implies that conventional milk, particularly private label milk, is seen by the consumer more as a necessity than manufacturer brand milk. The latter is consistent with the findings of Cotterill and Samson (2002) in that private label cheese, by virtue of being cheaper than brand-names, results in consumers being less sensitive to changes in its price. The specialty milk groups (lactose-free and organic) are, relatively speaking, quite responsive to price changes and behave more like luxury goods.

Table 2 also illustrates that all cross-price elasticities are positive, indicating various degrees of substitution among the brands as their prices change. Measured in percentage terms, the consumption of milk products are more sensitive to changes in the price of private label milk than the other way around, and particularly the specialty milks. Substitutions tend to be more intense within the same fat content and within milk categories, i.e. among conventional milk varieties or among specialty milk products.

The estimated cross-price elasticities for specialty milks provide an interesting insight into consumer behavior. For instance, when the price of lactose-free brands increases: (a) the only significant substitution occurs across lactose-free brands and (b) there is very limited substitution towards 1% fat but none towards whole milk. These results indicate that this category is practically the most differentiated across types of milk products, which can be explained by health restrictions affecting lactose-intolerant consumers who may substitute soy milk or non-milk products for lactose-free milk.

Table 2 also shows the impact of a 1% price increase across all milk products. Although all types of milk would lose ground to an outside good whose price had remained stable, specialty milks will suffer percentage losses in consumption which are twice are large as those in private label and manufacturing brand milks. The lesser loss suffered by these conventional milks can be attributed to both a smaller reaction to an increase in their own price and greater gains through relatively larger cross-price elasticities due to the higher prices of their rival brands. Those most negatively affected by this scenario are the organic milks closely followed by lactose-free milk products, whose consumers are more willing to abandon them as all milk prices increase.

Table 3 provides insight into price competition across milk brands. The highest percent markup, as reflected by the Lerner index, accrues to private label milk. This result is consistent with the finding of Chidmi and Lopez (2007) for breakfast cereals that the most basic type of cereal (Corn Flakes) had the highest retail markup, thanks partly to its having the lowest own-price elasticity among competing breakfast cereals. Another way to look at it is that lower marginal costs for private label milks allow for lower prices that still yield a hefty percent markup.

Although specialty milks sell for roughly twice the price of conventional milk, their percent price-cost margins are smaller due to significantly higher marginal costs and larger price elasticities. This is the case for organic milks and, especially, for lactose-free milks, whose overall results-- high own-price elasticities, limited capacity to benefit from other milks' price increases, and high retail marginal costs-- suggest that significant across-the-board price increases, like the ones experienced recently due to higher energy prices, could yield market share losses for lactose-free milk suppliers, unless they were able to stimulate demand through advertising and promotion or set smaller price-cost margins to lower prices.

Conclusions

The estimation of a random coefficients demand model using scanner data for the market of fluid milk in Boston adds to the literature an example of how this methodology sheds light on consumer behaviour and producer opportunities within markets with a large number of differentiated products. In this article we identify consumers' preferences for different types of milk as a function of their own personal characteristics and the products' characteristics.

Empirical results showed that consumers with children yield higher price elasticities and lean toward conventional types of fluid milk with some degree of milk fat, while higher income levels yield lower price elasticities and lead buyers towards specialty milks with lower fat levels. Another interesting finding is that an increase in prices, whether of a single variety or across the board, punishes more higher-than lower-priced brands, as well as those varieties for which there are close substitutes.

Overall, this article lends support to previous studies which similarly found that more basic products-- in this case private label milks-- benefit from greater price-cost margins, thanks to their lower marginal costs and to their lower own-price elasticities which derive in turn from the belief among consumers that they are invariably the cheaper option among all available comparable goods.

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Table 1: Demand Parameter Estimates.

		………	..Interactions..	………
	Mean utility	Income	Persons <15	Unobserved
Constant	-0.39 (0.29)			
Price	-0.87 (0.10)	0.19 (0.58)	-0.25 (0.10)	-0.25 (0.24)
Fat	0.13 (0.08)	-0.70 (0.40)	0.14 (0.04)	0.07 (0.51)
Organic	-2.36 (1.21)	0.57 (2.24)	0.27 (0.99)	-0.59 (1.92)
Lactose free	-3.72 (1.17)	0.48 (3.80)	-0.63 (0.59)	-0.49 (2.71)

Note: Standard errors in parenthesis

Table 2: Own-and Cross-Price Elasticities for Selected Milk Brands.

	Private Label		**Hood**		**Organic Cow VT**		**Lactose-Free** Morningstar	McNeil	Impact of a general 1% price increase
Private Label	1%	3.25%	1%	3.25%	1%	3.25%	1%	1%	
1% fat	-1.98	0.23	0.07	0.05	0.01	0.00	0.01	0.01	-0.83
3.25% fat	0.17	-1.89	0.06	0.08	0.00	0.00	0.00	0.00	-0.92
Hood									
1% fat	0.21	0.22	-2.55	0.05	0.01	0.00	0.01	0.01	-1.19
3.25% fat	0.14	0.32	0.06	-2.43	0.00	0.00	0.00	0.00	-1.17
Organic Cow of VT									
1% fat	0.22	0.16	0.09	0.04	-4.09	0.01	0.02	0.02	-2.53
3.25% fat	0.18	0.25	0.07	0.06	0.01	-3.80	0.01	0.01	-2.43
Lactose-Free									
Mornin..1% fat	0.24	0.12	0.12	0.04	0.02	0.01	-8.52	0.47	-2.35
McNeil 1% fat	0.26	0.13	0.13	0.04	0.02	0.01	0.41	-7.46	-2.26

Table 3: Lerner Indices and Related Statistics.

	Average price ($/gal)	Marginal cost	Price - marginal cost	Own-price elasticity	Lerner index
Conventional					
Private Label 0%	2.49	1.28	1.21	-2.05	0.49
Private Label 1%	2.49	1.23	1.26	-1.98	0.51
Private Label 2%	2.57	1.33	1.24	-2.07	0.48
Private label 3.25%	2.66	1.25	1.40	-1.89	0.53
Garelick 0%	2.96	1.80	1.16	-2.56	0.39
Garelick 1%	2.59	1.40	1.19	-2.18	0.46
Garelick 2%	3.06	1.84	1.22	-2.51	0.40
Garelick 3.25%	3.05	1.79	1.26	-2.42	0.41
Hood 0%	3.02	1.88	1.14	-2.64	0.38
Hood 1%	3.01	1.83	1.18	-2.55	0.39
Hood 2%	2.96	1.76	1.20	-2.48	0.40
Hood 3.25%	3.02	1.78	1.24	-2.43	0.41
Organic					
Organic Cow VT 0%	5.18	3.95	1.23	-4.22	0.24
Organic Cow VT 1%	5.18	3.91	1.28	-4.09	0.25
Organic Cow VT 2%	5.11	3.81	1.31	-3.92	0.26
Organic Cow VT 3.25%	5.17	3.80	1.37	-3.80	0.26
Lactose-Free					
Morningstar 0%	5.24	4.22	1.02	-5.06	0.19
Morningstar 1%	5.38	4.71	0.67	-8.52	0.12
Morningstar 2%	5.74	5.07	0.67	-8.46	0.12
McNeil 0%	5.07	4.52	0.55	-8.65	0.11
McNeil 1%	5.17	4.50	0.67	-7.46	0.13
McNeil 2^	5.02	4.19	0.83	-6.04	0.17

Figure 1: Mean Fat Parameters by Income Quartiles

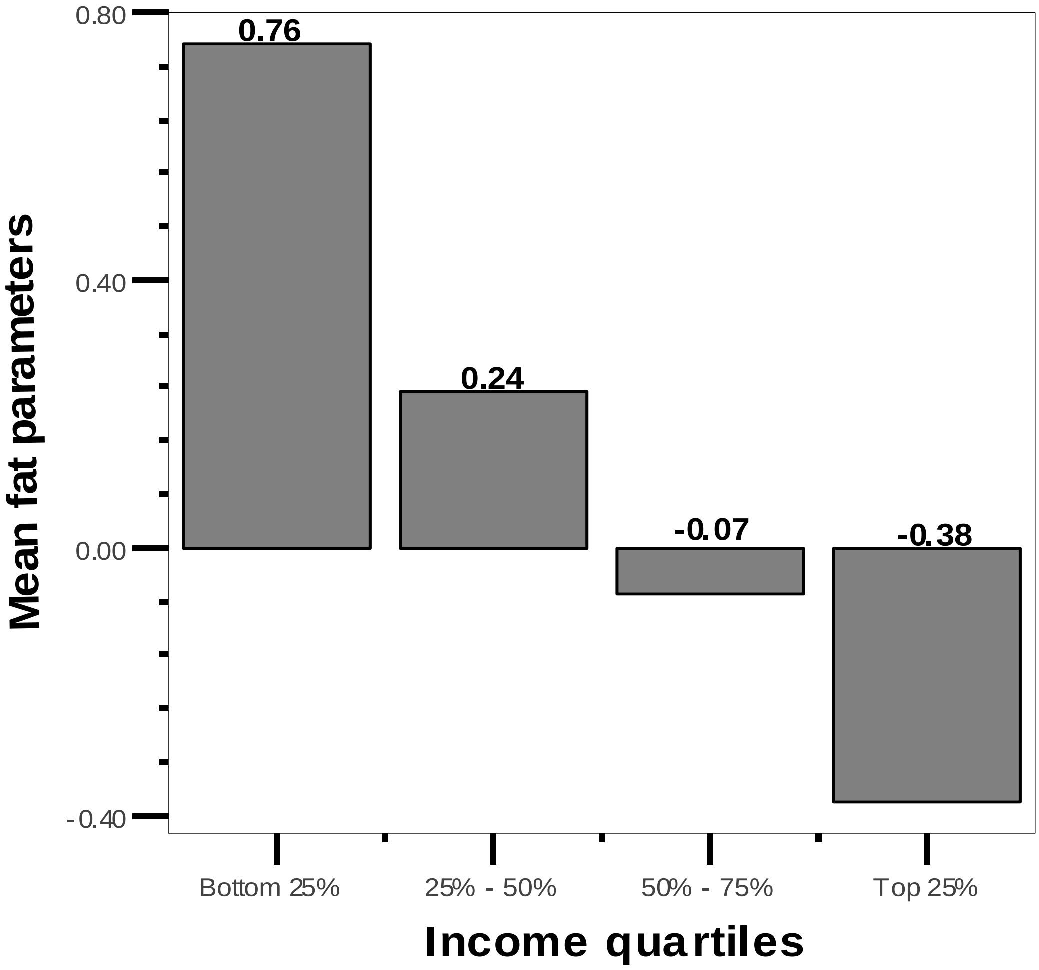
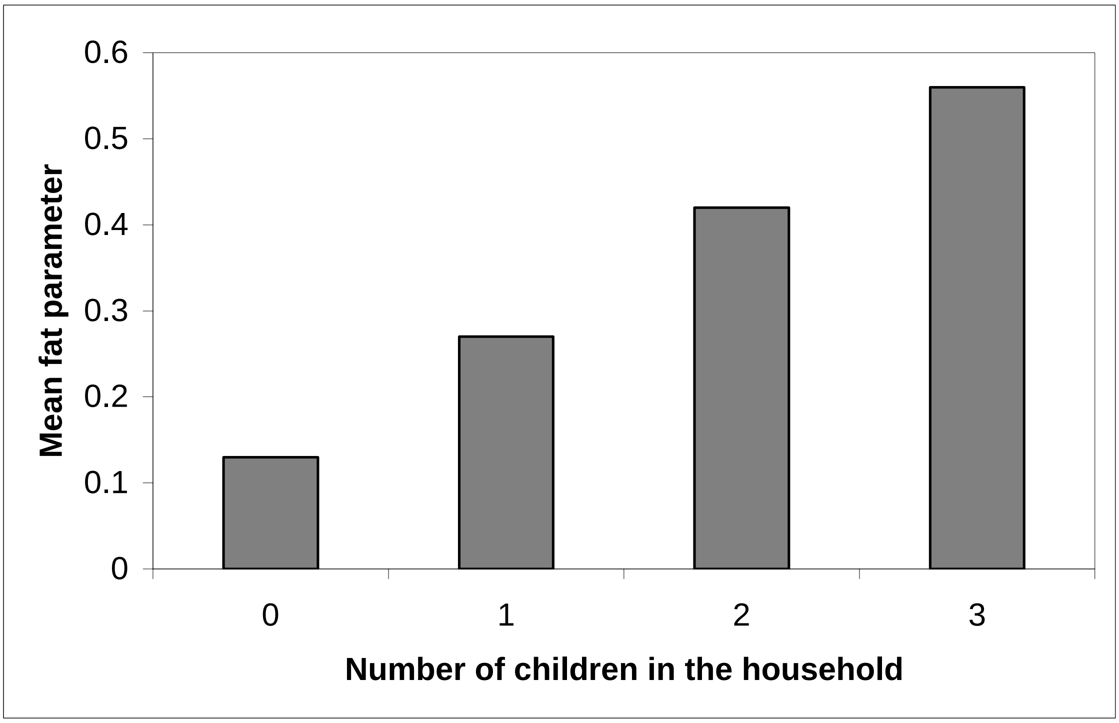


Figure 2: Mean Fat Parameters by Number of Children.



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Food Marketing Policy Center
1376 Storrs Road, Unit 4021
University of Connecticut
Storrs, CT 06269-4021

Tel: (860) 486-1927
FAX: (860) 486-2461
email: *fmpc@uconn.edu*
http://www.fmpc.uconn.edu