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DEMAND FOR DIFFERENTIATED MILK PRODUCTS: IMPLICATIONS FOR PRICE COMPETITION

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Abstract:

We apply the Berry, Levinsohn and Pakes (1995) model to scanner data from Boston supermarkets augmented with consumer characteristics data in order to analyze consumer choices and price competition in a differentiated fluid milk market. Milk characteristics include price, fat content, brand name and the organic and/or lactose-free nature of the product. Empirical results show that consumer valuation of fat decreases with income but increases with the number of children. Low-fat and specialty milks, such as organic and lactose-free milks, are preferred by high-income consumers with no children. Although all milks are price elastic at the individual brand level, the cross-price elasticities are quite low and negligible for specialty milks. Based on calculated Lerner indexes, private label milks have the highest percent markups despite their lower prices, while specialty milks have the lowest markups despite their higher prices, which attests to a greater degree of market power for conventional and particularly for private label milk.

Keywords: Demand analysis, Random coefficients model, Milk, Consumer behavior, Retail pricing, Markups, Competition.
JEL Classification: D12, D40, L11, L81

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Demand for Differentiated Milk Products: Implications for Price Competition

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1. Introduction.

The number of milk product choices in U.S. supermarkets has expanded considerably in the last decade. 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 greatly increases the number of parameters making conventional 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 dimensionality 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 differentiated 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 recent and flexible models is the one by Berry, Levinsohn and Pakes (1995; henceforth BLP), which solves the problems of dimensionality, consumer heterogeneity, and endogeneity 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).

This article applies the BLP model to a sample of fluid milk products in the Boston market area. With few exceptions (Junko et al. 2001; Junko, Susuki and Kaiser, 2002; Cotterill and Dhar, 2003), previous empirical studies on milk demand have typically been done at either the national level or have assumed product homogeneity in their analysis (Johnson, Stonehouse and Hassan, 1992; Chidmi, Lopez and Cotterill, 2005). However, focusing on the substantial variation of fluid milk products in one city market allows us to look more closely at the patterns of substitution and consumer response.

The Boston milk market has given rise to interesting political and research debates regarding retail market power and price transmission issues (Cotterill and Franklyn, 2001; Lass, 2005; Chidmi, Lopez and Cotterill, 2005; Canan and Cotterill, 2006). Given the availability of scanner data at the product brand level and the substantial variation of milk product and consumer characteristics, this market provides a good opportunity for a case study in analyzing both the demand for differentiated milk products and the implications of price competition. We use product brand-level, four-week data on milk at the four leading supermarket chains in the Boston area from 1998 to 2000. These data are combined with information 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, thus providing a detailed picture of consumer behavior and price competition in this market. Because product differentiated milk demand has been estimated using scanner data with other econometric models, either in Boston (Cotterill and Dhar, 2003; Canan and Cotterill, 2006) or elsewhere (Suzuki et al., 2001; Suzuki and Kaiser, 2002), our results can be directly compared to those from previous work.

2. The Model

We assume, as in a BLP model, 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) $U_{ij} = \alpha_i p_j + \beta_i x_j + \varepsilon_{ij} \cdots \forall i = 1,\ldots,\eta$ consumers

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. Since individual taste parameters are related to 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 α_i and β_i back into (1) yields

(2) $U_{ij} = p_j + \mu_{ij} + \varepsilon_{ij}, \forall i = 1, \ldots, \eta$ consumers

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 permit for the possibility that a consumer does not choose any of the *J* products defined above. The outside good also helps 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 a product that maximizes their utility, the market share of each product equals the probability that the specific product is chosen, which is given by

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

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

With respect to the supplies of the differentiated products, we assume that supermarkets take their 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 for calculating the marginal cost (since prices and the shares are observed) as well as the gross price-cost margins at the brand level. The Lerner indexes of oligopoly, which measure market power at the brand level and equal to the inverse of the absolute value of the elasticity of demand facing each brand, can be simply obtained as $L_j=(p_j-c_j)/p_j$, .

3. Data and Estimation

The data consist of two sets: milk sales and consumer characteristics. The milk sales data came from the Information Resources Incorporated (IRI) 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 (includes Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, and Worcester counties) during 27 four-week periods from July 1998 to July 2000 (see Figure 1 for a map). These four supermarket chains accounted for approximately 70% of the grocery market share in the Boston area in 1999 (U.S. General Accounting Office, 2001), and the area included accounts for more than 80% of the total population of Massachusetts (Trade Dimensions. Market Scope, 2000 and Ecomagic homepage).

Product characteristics include: brand name (with private label or store brand considered as one brand name, Garelick, Hood, Organic Cow of Vermont, Morningstar, and McNeil), fat content (0, 1, 2% and whole milk, which is 3.25% fat), lactose content, and organic milk. Other characteristics such as calories or sugar contents, typically observed in different amounts in other products, are homogeneous across types of milk with the same fat content, and thus, are not considered here. After dropping all milk types 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 are computed by dividing the dollar sales of each product by volume sold. Market shares for each product are computed with respect to the potential market for milk, which was calculated by multiplying the total population of the Boston area by the average U.S. per capita milk consumption (USDA/ERS webpage). The potential market size thus includes all the different types and brands of fluid milk bought, not only at grocery stores but also at gas stations and convenience stores. The outside good is defined as the part of the potential market that is not considered in the sample, that is, the total amount of fluid milk sold in the Boston area that is either not part of the 22 milk products in the sample or that is sold in other retail outlets. As a result, the volume of milk included in that data set represents approximately 51% of the potential market.

Consumer characteristics for the Boston market are 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 four-week time periods, 250 observations on income and the number of persons under 15 years of age 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. 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 compiled, 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 use of instrumental variables 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 IRI milk sales dataset provided by the Food Marketing Policy Center. The estimated parameters derived from the demand model 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.

The estimated demand parameters were used to calculate price elasticities by simulation of equation (4). The retail price-cost margins were calculated via equation (7). Given that we know retail prices, then, both the retail marginal costs and the Lerner indexes were calculated from the price-cost margins and milk prices. The results are presented in the following section.

4. 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 = $-2.36 + 0.57D_I + 0.27D_K - 0.59V_i$

(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 should be interpreted with caution, as they contain a high proportion of non-significant coefficients. They show an expected negative reaction to price increases, which diminishes with higher household income and a smaller 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 2 compares consumer valuations of milk fat content by income quartiles. The mean value of the fat parameter decreases consistently as income increases. The value 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 3 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.

This analysis also shows the extent of and the direction in which consumers substitute milk brands when their prices increase. In total, 484 own-and cross-price elasticities were computed (22x22). Given the difficulty of reproducing the large number of coefficients involved, Table 2 presents a selected group of price elasticities for eight milk products (64 in total), involving the 2 most popular choices for each milk type (private label, manufactured brands, organic and lactose-free). For the first three types these are the leading brand of 1% fat-content and whole milk. In the case of lactose-free milk, however, the two most popular choices are the 1% fat levels for the brands Morningstar and MacNeil.

As expected, all the own-price elasticities are negative, and those for the stores' Private Label obtain the smallest coefficients (more price inelastic), which indicates greater stickiness to the most basic choice. These findings imply that consumers see conventional milk, particularly private label milk, more as a necessity, and reinforce the conclusions of Cotterill and Samson (2002): 822, according to whom "… after having verified that Private Label is always cheaper, consumers seem to become less price sensitive to changes in Private Label price." More expensive specialty milks obtain higher own-price elasticities, behaving more like luxury goods and indicating the greater willingness of consumers to abandon the habit of purchasing the more expensive varieties as their prices increase. Taken altogether, the values of the own-price elasticities obtained in this study (which cover from -1.98 for 1% low fat milk to -8.52 for 1% lactose-free milk), are within the same range of those found in previous studies focusing specifically on demand for milk in Boston. For instance, Cotterill and Dhar (2003) provides own-price elasticity estimates as high as -35 for Hood milk and -3.62 for private label milk, while Chidmi, Lopez and Cotterill (2005) obtained an estimate of -0.62 for aggregate milk in Boston.

Using scanner brand-level data in Japan, Junko, Suzuki and Kaiser (2002) find price elasticities in the range of -6.665 and -9.187, while Junko et al. (2001) find them on average to be approximately at -1.92 for fresh milk. Canan and Cotterill (2007) estimate the brand-level (albeit not supermarket-level) price elasticities to be between -5.16 for Hood and -0.866 for private label milk.

Table 2 also illustrates that all cross-price elasticities are either positive or zero, but their values differ considerably indicating various degrees of substitution among the brands as their prices change. In general, substitutions tend to be more intense within milk categories, i.e. among conventional milk varieties or among specialty milk products.

Furthermore, substitution is also greater among products with the same fat content, indicating that in the face of a price increase, consumers tend to substitute within types of products that retain most of the original features of the sort of milk they regularly purchased before.

The estimated own and cross-price elasticities for specialty milks provide an interesting insight into consumer behavior regarding specialty milks. When the price of one of the two lactose-free brands of milk increases: (a) many people choose to stop buying that product (b) some significant substitution occurs across lactose-free brands and (c) there is limited substitution towards other types of milk with 1% fat content, especially organic, but virtually 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 many of their usual consumers who are lactose-intolerant. In fact, these consumers' only options, in the face of a price increase, are to turn to the other lactose-free brand considered in this study or to substitute away from the products analyzed here, either by purchasing another lactose-free brand of milk pertaining to the outside good or by buying soy milk or non-milk products. The large values of these products' elasticities indicate that specialty milk consumers consider all these options after a price rise in the variety of milk they regularly purchased before.

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 as 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 as well as greater gains through relatively larger cross-price elasticities due to the higher prices of 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 efficiency and price competition across milk brands. The highest percent markup, as reflected by the Lerner index, accrues to private label milk thanks to lower marginal costs which allow for lower prices that still yield a hefty percent markup. 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.

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.

5. Conclusions

The estimation of a random coefficients demand model using fluid milk prices provided from scanner data for the Boston market area, illustrates how this methodology can be used to shed light on consumer behavior and producer opportunities in markets containing a large number of differentiated products. Consumers' preferences for different types of milk are identified as functions of their own personal characteristics and the products' characteristics. Empirical results show 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 finding is that an increase in prices, whether of a single variety or across the board, yield greater losses in higher priced milk types, such as organic and lactose-free specialty milks. Conventional milks, and especially private label's store milks, seem to be shielded by lower own-price elasticities and benefit more from other milks' price increases, as consumers tire of paying a premium for specialty milks as their prices rise further.

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 lower marginal costs and lower own-price elasticities. These 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.

	Mean utility	……..….. Income	..Interactions.. Persons <15	………. Unobserved
Constant	-0.39 (1.34)			
Price	-0.87*** (8.70)	0.19 (0.32)	-0.25*** (2.50)	-0.25 (1.04)
Fat	0.13 (1.62)	-0.70* (1.75)	0.14*** (3.50)	0.07 (0.13)
Organic	-2.36** (1.95)	0.57 (0.25)	0.27 (0.27)	-0.59 (0.30)
Lactose free	-3.72*** (3.18)	0.48 (0.12)	-0.63 (1.06)	-0.49 (0.18)

Note: t-values in parentheses. *, **, and *** represent, respectively, 10%, 5% and 1% levels of statistical significance.

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

	Conventional Milks				Specialty Milks				Impact of an overall 1% price increase
	Private Label		Manufactured Brand		Organic		Lactose-Free		
Brand name	Private Label		Garelick		Organic Cow of Vermont		Morningstar	McNeil	
Fat content:	1%	Whole milk	1%	Whole milk	1%	Whole milk	1%	1%	
Private Label									
1% fat	-1.98	0.23	0.09	0.05	0.01	0.00	0.01	0.01	-0.83
Whole	0.17	-1.89	0.07	0.08	0.00	0.00	0.00	0.00	-0.92
Garelick									
1% fat	0.21	0.23	-2.18	0.08	0.01	0.00	0.01	0.01	-0.90
Whole	0.18	0.32	0.07	-2.42	0.00	0.00	0.00	0.00	-1.19
Organic Cow of Vermont									
1% fat	0.22	0.16	0.10	0.04	-4.09	0.01	0.02	0.02	-2.53
Whole	0.18	0.25	0.078	0.06	0.01	-3.80	0.00	0.01	-2.43
Morningstar									
1% fat	0.24	0.12	0.10	0.04	0.02	0.01	-8.52	0.47	-2.35
McNeil									
1% fat	0.26	0.13	0.12	0.04	0.02	0.01	0.41	-7.46	-2.26

Table 3: Lerner Indexes 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: Definition of the Boston Market Area

Figure 2: Mean Fat Parameters by Income Quartiles

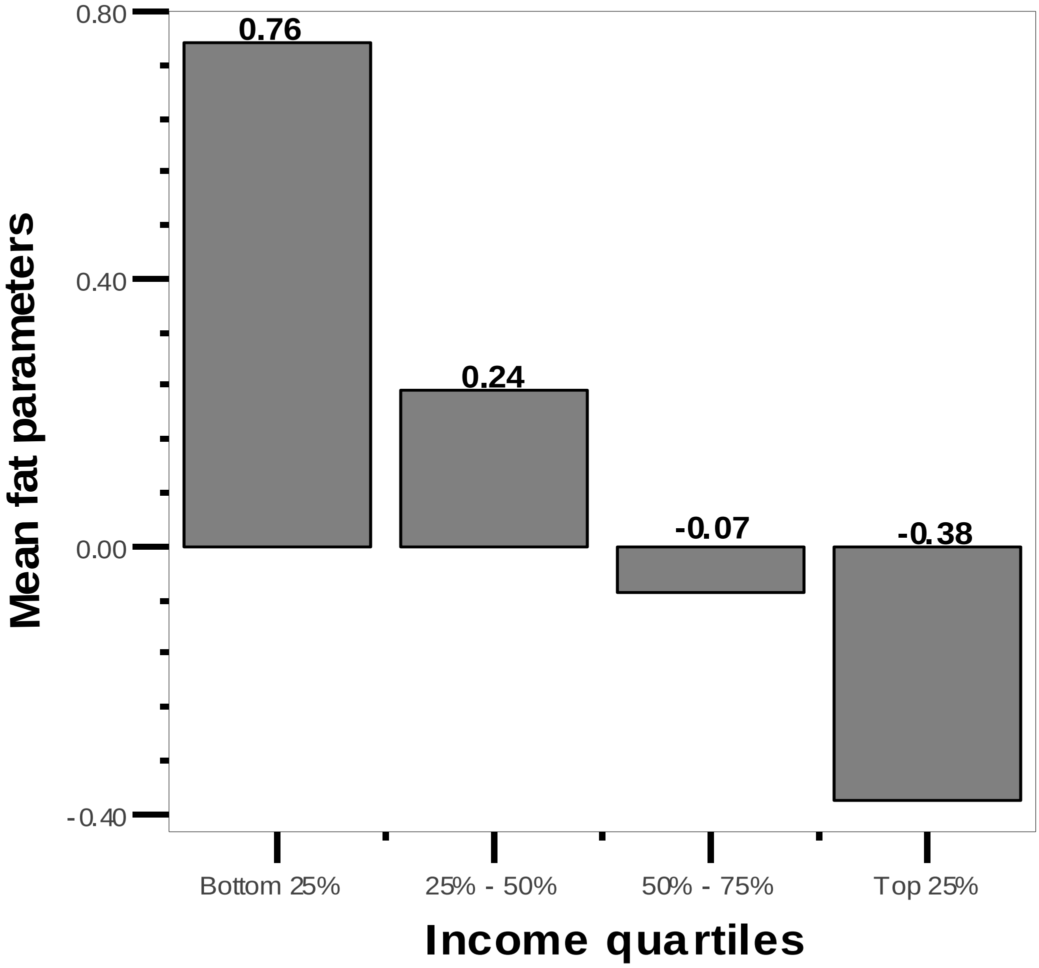
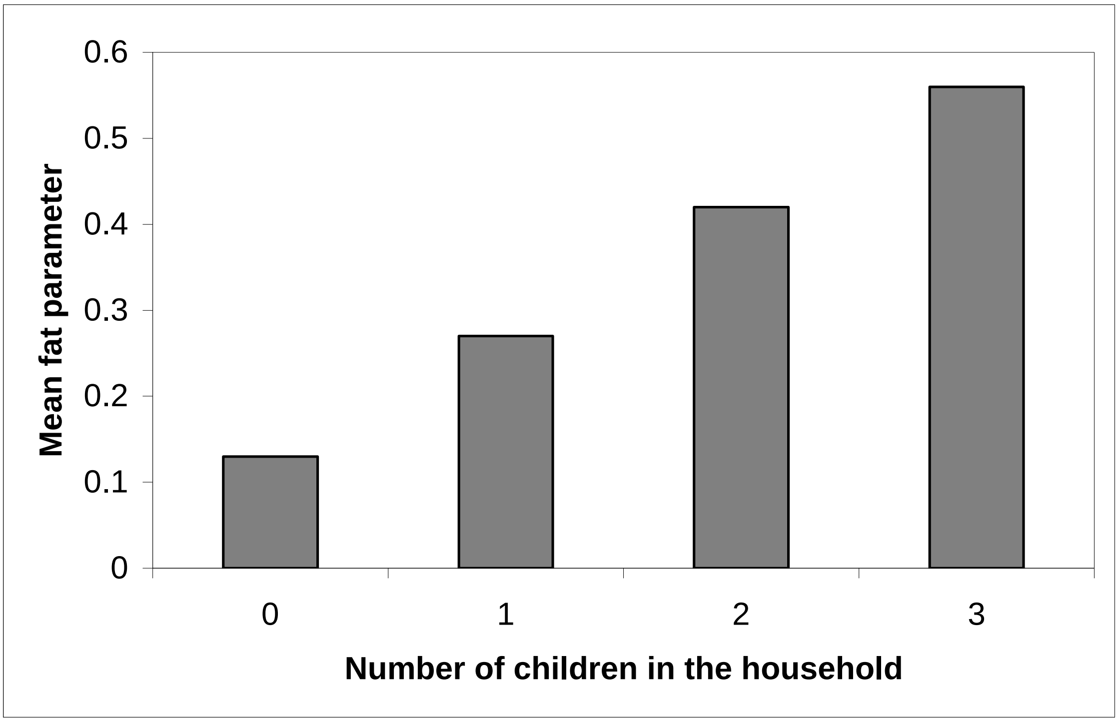


Figure 3: Mean Fat Parameters by Number of Children.



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