Assessing economic and demographic factors that influence United States dairy demand¹

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ABSTRACT

Low-fat dairy products are key components of a healthy diet for all Americans. As the USDA increases its focus on nutrition and healthy eating, it is important to understand the underlying demands for dairy products, both the healthy and the less healthy ones. The consumption of fluid milk products has decreased over the last decade, whereas milk used for manufactured dairy products such as cheese, ice cream, yogurt, and butter, and for use as an ingredient in other food products, has risen. The objective of this study is to determine the effects of changes in demographic variables, retail prices, and total dairy expenditure on at-home consumption of dairy products, using purchase data from Nielsen 2007 Homescan (ACNielsen, New York, NY) data. To derive the demand elasticities for 16 products, a censored Almost Ideal Demand System model is used. Results reveal that demographic variables do have effects on the purchase of the 16 products, and own-price elasticities are 1 or greater for all 16 products for both uncompensated and compensated elasticities except 4: ice cream, refrigerated yogurt, processed cheese, and margarine. A substitution relationship exists among all fluid milk categories, natural and processed cheese, low-fat ice cream, and refrigerated yogurt, butter, and margarine.

Key words: dairy demand, dairy industry, Nielsen data

INTRODUCTION

Analysis of Consumer Demands

Welfare analysis of government food programs and market analysis of consumer food demands both re-

quire information on consumer responses to price and income changes. Given the large array of food products in the consumer's choice set, analysis of price and expenditure elasticities requires estimation of a very large demand system with time-series or cross-sectional data. One approach taken by many analysts is to limit the scope of analysis to a reduced set of products selected for any of several reasons. One such set is milk and dairy products.

The United States dairy industry provides a wide array of milk and dairy goods to consumers that deliver attributes of farm milk in many forms. The significant role played by low-fat fluid milk products in promoting health, especially of young children, is often emphasized, as is the importance of many other dairy products as sources of vitamins and minerals that support bone health. Deriving insights from the economic analysis of the milk and dairy products as a group provides important information for policymakers, the dairy industry, and retailers.

Over the last decade, milk use for manufactured dairy products such as cheese, ice cream, yogurt, and butter, and for use as an ingredient in other food products, has risen (Blayney, 2010). Marketers of processed and manufactured dairy products are interested in knowing consumer responses to changing prices of individual dairy products, including information on whether products are complements or substitutes. How purchases of products are related to changes in expenditures is also of interest. Policy analysts also require such information as they try to determine the effects of the food pyramid guidelines, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), and other governmental programs designed to support nutritional health.

The objective of this study was to estimate demand and demographic elasticities that can be used in policy analysis by researchers in academic institutions and policy-oriented agencies. Elasticities are major tools in the economist's toolbox. Simply put, an elasticity of variable y with respect to variable x is the percentage change in y given a 1% increase in x . For example, an

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own-price demand elasticity of -0.7 implies that a 1% price increase decreases quantity demanded by 0.7%. Elasticities in economic studies are most often related to price, and income (or expenditure) effects, but interest in examining demographic effects has increased as well.

The dairy product categories selected for this analysis, in addition to margarine, represent major dairy products produced and consumed in the United States. They also represent the usage of a very large share of the milk production made available by US dairy farmers. An analysis of this group of products also offers a glimpse of substitution and complementary relationships among them as sources of milk solids demanded by consumers.

Empirical Literature of Dairy Product Demands

Although numerous studies have focused on aggregated dairy products, few have analyzed the many disaggregated products for most staple dairy goods available in retail stores. The differences in demand for disaggregated ice cream, yogurt, milk, and cheese, took—and still hold—center stage. This study makes no effort to catalog all relevant earlier studies; rather, the results from key studies across a historical time period are summarized.

An early study by Boehm and Babb (1975) used 2 separate models to estimate price and expenditure elasticities for dairy products using cross-sectional data and time series data from the United Dairy Industry Association (Rosemont, IL). Findings from the cross-section analyses, which was described as the long-run response analysis showed that national average own-price elasticities for whole milk (-1.70), 2% milk (-1.33), buttermilk (-1.52), cottage cheese (-1.29), processed cheese (-1.71), and canned milk (-1.33) were all elastic, whereas other dairy products, such as ice cream (-0.42), ice milk (-0.56), American cheese (-0.44), butter (-0.76), and yogurt (-0.31) were less than 1. All of the expenditure elasticity estimates for the above dairy products were also less than 1.

Using the Almost Ideal Demand System (AIDS) model, Gould et al. (1990) estimated the demand for whole milk and low-fat milk. The own-price elasticity estimates for whole milk were -0.32 and was -0.44 for low-fat milk, and expenditure elasticities were 0.66 and 0.06. Gould (1996) also examined the demand for whole milk, 2% milk, and 1% or skim milk. Using Nielsen Homescan (ACNielsen, New York, NY) data from April 1991 to March 1992, he found the own-price elasticities to be -0.80 for whole milk, -0.51 for 2% milk, and -0.59 for 1% or skim milk. Expenditure elasticities were all slightly less than 1.

Kaiser and Carlos Reberte (1996) used monthly data from 1986 through 1992 to determine if any statistical difference exists in sales responsiveness to generic advertisement for whole, low-fat, and skim milk products. Their findings show that the own-price elasticities for whole milk (-0.003), low-fat milk (-0.14), and skim milk (-0.30) are all inelastic. All 3 fluid milks had significant long-term sales responsive to generic advertising.

Heien and Wessells (1990) employed the AIDS model to estimate a demand system, which includes 11 food items with focus on dairy. A censored regression approach was compared with an uncensored approach using data retrieved from the USDA 1977–1978 household food consumption survey. Own-price elasticities for milk, cheese, cottage cheese, butter, margarine, and ice cream were all inelastic under the censored demand estimation, but were elastic using the uncensored approach for ice cream, cottage cheese, and butter. The uncensored demand model expenditure elasticities were lower for all items than for the censored demand model, ranging from 0.61 to 0.89.

Maynard and Liu (1999) estimated 3 separate models, a quantity-dependent double-log specification, a linearized AIDS model, and a differential demand systems model, using weekly retail scanner data from Nielsen for the years 1996 through 1998. Results from the linearized AIDS model revealed that own-price elasticities for flavored milk, shredded cheese, frozen yogurt, and frozen novelties were elastic. The estimates from the differential demand systems showed demands for the aforementioned dairy products as being elastic but also provided elastic results for butter and ice cream.

The demand for frozen desserts were analyzed by Maynard and Narayanan (2002), using an ordinary (quantity-dependent) synthetic conditional demand system model framework. Elasticity estimates were derived for 7 products including ice cream, frozen yogurt, sherbet, sorbet, branded frozen novelties, private-label frozen novelties, and other packaged frozen products. The estimates of compensated own-price elasticities for ice cream, frozen yogurt, sherbet, sorbet, branded frozen novelties, private label frozen novelties, and other packaged frozen products were -1.30 , -1.72 , -1.43 , -0.71 , -2.39 , -1.59 , and -2.37 , respectively.

Schmit et al. (2002) used a 2-step model with sample selection and Nielsen Homescan data to determine the effects that generic advertisements have on US at-home demand for fluid milk and cheese. Their unconditional purchase elasticities reveal that low-fat and skim milk products are positively influenced by household size, members of household age 17 and younger, and 65 and older, and long-run generic milk advertising. Other unconditional purchase elasticities show that most, if not

all, cheese products are positively influenced by household income, household size, and members of household age 17 and younger.

Bergtold et al. (2004) analyzed various processed foods, including cheese products using the flexible and separable translog (FAST) multi-stage demand system. They estimated unconditional own-price elasticities for nonshredded cheese, shredded cheese, imitation cheese, and cheese spreads yield of -0.70 , -0.95 , -1.84 to -1.90 , and -1.88 to -1.90 , respectively, similar in size to the cheese elasticities estimated in the present study.

One study most comparable to the present analysis was conducted by Chouinard et al. (2010). Using weekly Information Resources Inc. (IRI; Chicago, IL) InfoScan scanner data for the years 1997 through 1999, price and income elasticities were estimated using an AIDS model that is linear in income and linear and quadratic in prices (LQ-IDS). Findings showed that the own-price elasticities for 1% milk (-0.882), 2% milk (-0.788), no-fat or skim milk (-0.622), whole milk (-0.742), natural cheese (-0.721), process cheese (-0.773), shredded cheese (-0.253), butter (-0.41), ice cream (-0.803), and flavored yogurt (-0.773) were smaller than the elasticities estimated by our censored demand system.

The primary difference between the present study and Chouinard et al. (2010) is that this study uses cross-sectional data collected over 12 months for the year 2007, whereas Chouinard et al. (2010) used aggregated weekly data over 3 years, January 1997 to December 1999. Also, the IRI InfoScan data cover just 23 US cities, a data set not as extensive as the Nielsen Homescan data, representing a sample of the US 2007 population. The use of these 2 data sets requires different econometric analyses, likely to produce different elasticity estimates.

This study also differs in that it uses finer distinctions in the dairy categories—bulk ice cream, ice milk/sherbet, refrigerated yogurt, frozen yogurt, drinkable yogurt, whole milk, reduced-fat milk, canned milk, natural cheese, processed cheese, cottage cheese, butter, and margarine—to decrease potential aggregation biases in estimation. A censored demand system is specified and estimated using 2007 Nielsen retail household scanner data to determine the effect that changes in retail prices, consumer income, and demographic factors will have on at-home dairy product consumption.

MATERIALS AND METHODS

Design and Procedures

The sample used in this study contains a significant proportion of zero purchases of the 16 products. Statistical estimation procedures not accounting for this censoring in the dependent variables can produce unreli-

able (biased and inconsistent) parameter and elasticity estimates. A large menu of statistical procedures exists for the estimation of demand systems with censored dependent variables. We extend the Tobit (censored) linear equation system procedure of Amemiya (1974) to nonlinear demand functions, along with a mapping mechanism suggested by Wales and Woodland (1983) to impose the adding-up restriction implied by consumer (utility maximization) theory. This mapping procedure is also used in Dong et al. (2004).

To focus on dairy products, the empirical analysis for this study is based on the assumption that these dairy products are separable from all other consumer goods. Further, as in other censored statistical models, the censored demand system is expressed in terms of latent equations (Amemiya, 1974). The latent share system of the AIDS model (Deaton and Muellbauer, 1980) is expressed as

$$S^* = A + \gamma \ln P + \theta \ln Y + \varepsilon, \quad [1]$$

where S^* is an M -vector of latent expenditure shares on dairy products, P is an M -vector of prices, and $Y = y^*/P^*$ is the total dairy expenditures (y^*) deflated by a translog price index (P^*), and ε is an M -vector of error terms. Demographic characteristics, an N -vector D , are incorporated by translating the M -vector parameter A in equation [1] such that $A = \beta D$; γ , θ , and β are conformable parameters.

Demand system estimation is about imposing theoretical restrictions (besides accommodating special data features) in the statistical estimation. Important theoretical restrictions include adding-up, symmetry, and homogeneity (Deaton and Muellbauer, 1980). First, given the budget constraint, the adding-up restriction requires that the latent shares sum to 1. This adding-up condition can be attained through parametric restrictions: $\iota'\beta = [1, 0, \dots, 0]$, $\iota'\theta = 0$, and $\iota'\gamma = [0, 0, \dots, 0]$, where ι is an M -vector of ones. Further, the symmetry restrictions are imposed by allowing γ to be a symmetric matrix. Then, adding-up and symmetry together imply homogeneity.

With the adding-up restriction, the joint density function of ε is degenerate (and, therefore, the error covariance matrix is singular) so estimation must be based on $M - 1$ latent share equations. An equation is dropped from the system, as is the associated element from the error vector ε . The resulting error vector is assumed to be distributed as $(M - 1)$ dimensioned normal with zero means and a finite and positive definite covariance matrix.

The mapping of the latent shares vector (S^*) to the observed share vector (S) must take into account that the elements of S lie within the unit simplex and sum

to unity for each observation. One such mapping is introduced by Wales and Woodland (1983):

$$S_i = S_i^* / \sum_{j \in J} S_j^* \quad \text{if } S_i^* > 0$$

$$= 0 \quad \text{if } S_i^* \leq 0, \quad i = 1, \dots, M, \quad [2]$$

where J is the set of subscripts for all positive shares. The mapping of S^* to S in equation [2] has the property that the resulting density function is invariant with respect to the element of S^* excluded. Assume that at least 1 of the 16 products is purchased; then, the likelihood contribution can be written according to the observed purchase pattern (sample regimen) for each household. Consistent and efficient model estimates can be obtained by maximizing the sum of log-likelihood contributions over the sample, with multiple probability integrals evaluated with a probability simulator (Hajivassiliou, 1993). Details can be found in Dong et al. (2004).

Upon estimation, the latent equation system [1] and mapping rule [2] are used to simulate demand elasticities. Specifically, at observed values of the right-hand side variables in [1] and a randomly drawn $(M-1)$ -dimensioned normal variate $\tilde{\varepsilon}^r$ for the r th draw, a latent share vector $\tilde{s}^{*r} = [\tilde{s}_1^{*r}, \dots, \tilde{s}_{M-1}^{*r}]'$ is obtained which, along with the mapping rule [2], generates observed share vector $\tilde{s}^r = [\tilde{s}_1^r, \dots, \tilde{s}_{M-1}^r]'$. Expected shares for each household is then obtained by averaging over the R draws:

$$E(s_i) = \frac{1}{R} \sum_{r=1}^R \tilde{s}_i^r, \quad i = 1, \dots, M-1. \quad [3]$$

Then, Marshallian own-price elasticities and total expenditure elasticities for goods 1, ..., $M-1$ are obtained by differentiating the sample mean of [3], and elasticities for the M goods are derived using the adding-up restriction. Finally, compensated elasticities are derived by applying the Slutsky equation. The above simulation procedure is similar to that of Phaneuf et al. (2000) in welfare calculations with a censored recreation demand system.

Data

Data for the dairy products are compiled from Nielsen's 2007 Homescan data. The sample was drawn from a nationally representative panel of US households. Each household is supplied with a scanner device to record at-home grocery items purchased at all retail outlets with the uniform product code (UPC) or a des-

ignated code (for random weight food items) for all food items purchased for at-home consumption from all retail outlets. The data include product characteristics, quantity, and expenditure for each food item. Household demographic data are also available in Homescan. The Homescan data are used to determine household behavior, expenditures, and volume aggregated over 12 months for each household. Also, from this data, a unit value is estimated for each commodity and each household.

The full Homescan panel consists of 63,031 households that purchased at least one of the 16 products. Nielsen data only contain retail purchases for at-home use. Thus, one of the limitations to using the Nielsen data are any of the 16 products consumed away-from-home at establishments such as fast-food restaurants, dine-in restaurants, cafeterias, schools, among others, are excluded. If any of the products being analyzed have a significant away-from-home consumption, estimated economic measures such as per capita consumption or elasticities must be evaluated with that in mind.

For this study, 5 types of fluid milk products (whole milk, 1% milk, 2% milk, skim milk, and canned milk), 2 types of ice creams (regular ice cream and low-fat ice cream), 2 types of yogurts (refrigerated yogurt and frozen yogurt), 3 types of cheese (natural cheese, cottage cheese, and processed cheese), sour cream, creamer, butter, and margarine comprise the 16 product categories. The 15 dairy products were chosen because they accounted for a very large share of the total milk production made available by US dairy farmers. Margarine, which is very similar to butter and often sold side-by-side in retail stores, was also included in the dairy demand system as a strong substitute for butter. Other dairy products such as whipped cream and dry milk were also considered, but because of their small share of the total dairy expenditure and large numbers of zero purchases, they were eliminated from the analysis.

RESULTS AND DISCUSSION

Sample Statistics

According to Nielsen 2007 retail Homescan data, on average, consumers purchased more reduced-fat and whole milks than they did any other dairy products (Table 1). Dairy expenditures are largest for reduced-fat milk and ice cream; the 2 account for almost 42% of the total dairy expenditures. Of the 7 products measured in dry ounces, natural cheese, followed by processed cheese and butter had the highest prices per dry ounce.

In addition to quantities and expenditures, definitions of demographic variables are displayed in Table

Table 1. Variable definitions and sample statistics (sample size¹ = 63,061)

Variable	Mean	SD	% of Pur. HH ²
Quantity (L or kg per household over 12 mo)			
Ice cream (L)	17.50	23.71	85
Low-fat ice cream (L)	0.21	0.84	15
Refrigerated yogurt (kg)	9.62	14.98	76
Frozen yogurt (kg)	0.47	3.85	8
Whole milk (L)	18.02	51.63	41
1% milk (L)	17.34	52.87	34
2% milk (L)	37.35	74.78	61
Skim milk (L)	23.73	62.22	36
Canned milk (L)	0.99	3.47	41
Natural cheese (kg)	3.41	4.86	81
Processed cheese (kg)	4.10	4.61	90
Cottage cheese (kg)	2.40	5.14	53
Sour cream (kg)	1.63	2.46	65
Creamer (L)	2.09	5.43	28
Butter (kg)	2.31	3.79	61
Margarine (kg)	4.31	5.51	76
Expenditure (\$ spent per household over 12 mo)			
Ice cream (L)	0.97	1.33	
Low-fat ice cream (L)	0.02	0.07	
Refrigerated yogurt (kg)	0.89	1.38	
Frozen yogurt (kg)	0.03	0.26	
Whole milk (L)	0.50	1.36	
1% milk (L)	0.45	1.32	
2% milk (L)	0.96	1.82	
Skim milk (L)	0.58	1.45	
Canned milk (L)	0.08	0.24	
Natural cheese (kg)	0.83	1.13	
Processed cheese (kg)	0.75	0.83	
Cottage cheese (kg)	0.27	0.58	
Sour cream (kg)	0.16	0.23	
Creamer (L)	0.15	0.56	
Butter (kg)	0.38	0.62	
Margarine (kg)	0.30	0.38	

¹Sample size includes all households that purchased at least 1 of the 16 products.

²Percentage of households that purchased a particular dairy product.

2. Variables used in the analysis include household size and dummy variables representing children under the age of 6 yr old, teenagers 13 to 17 yr old, single head of household, race (white, black, and Asian), regions (East, Central, and South), and 6 household income categories ranging from 0 to \$149,999. The reference categories are dropped in the estimation to avoid singularity problems. The dropped demographic dummy variables include Western region, other race head of household, and household income $\geq$ \$150,000.

Compensated Demand Elasticities

The compensated (Hicksian) elasticities allow income to change to “compensate” for the price change. The compensated price elasticities for dairy products are presented in Table 3. All own-price elasticities are negative and statistically significant at $P < 10\%$ or better significance level. According to our findings, the dairy products most responsive to changes in price are low-fat ice cream (-1.20), frozen yogurt (-1.18), whole milk

(-1.93), 1% milk (-1.73), 2% milk (-1.60), skim milk (-2.30), canned milk (-1.32), natural cheese (-1.72), cottage cheese (-1.71), sour cream (-1.33), creamer (-2.53), and butter (-1.78). The derived own-price elasticities for cottage cheese and butter are similar to those derived from the differential model used by Maynard and Liu (1999), and the uncensored model of Heien and Wessells (1990; with the exception of frozen yogurt)—in that elasticity estimates for this study are close to or greater than 1. Maynard and Veeramani (2003) also found the own-price elasticities for frozen yogurt (-1.64), sherbet/ice milk (-1.11), and branded novelties (-1.81) to be elastic and responsive to changes in price.

Based on the compensated own-price elasticities derived from the present study, a 1% decrease in the price of frozen yogurt, fluid milks, natural cheese, cottage cheese, sour cream, creamer, or butter will lead to a greater than 1% increase in the quantity demanded of these products. Other dairy commodity elasticities such as for ice cream, refrigerated yogurt, processed cheese,

Table 2. List of independent variables

Variable	Variable definition
Single head	= 1 if the head of household is single; = 0 otherwise
Children <6 yr old	= 1 if a child under 6 yr old is present in the household; = 0 otherwise
Teenagers	= 1 if person in the household is between 13 and 17 yr old; = 0 otherwise
Region	
Central	= 1 if the household resides in the Central region of the United States; = 0 otherwise
South	= 1 if the household resides in the Southern region of the United States; = 0 otherwise
West ¹	= 1 if the household resides in the Western region of the United States; = 0 otherwise
East	= 1 if the household resides in the Eastern region of the United States; = 0 otherwise
Race	
White	= 1 if the race of the household is Caucasian; = 0 otherwise
Black	= 1 if the race of the household is African-American; = 0 otherwise
Asian	= 1 if the race of the household is Asian-American; = 0 otherwise
Other ¹	= 1 if the race of the household is other American; = 0 otherwise
Household income	
≤\$19,999	= 1 if income of the household is ≤\$19,999; = 0 otherwise
\$20,000 to 34,999	= 1 if income of the household is between \$20,000 and 34,999; = 0 otherwise
\$35,000 to 49,999	= 1 if income of the household is between \$35,000 and 49,999; = 0 otherwise
\$50,000 to 69,999	= 1 if income of the household is between \$50,000 and 69,999; = 0 otherwise
\$70,000 to 99,999	= 1 if income of the household is between \$70,000 and 99,999; = 0 otherwise
\$100,000 to 149,999	= 1 if income of the household is between \$100,000 and 149,999; = 0 otherwise
≥\$150,000 ¹	= 1 if income of the household is ≥\$150,000; = 0 otherwise

¹Reference category.

and margarine are all less than 1, implying that a 1% drop in the price of these commodities will yield less than a 1% change in the quantity demanded. Our own-price elasticity for ice cream is lower than the estimate reported by Maynard and Narayanan (2002).

The highly elastic estimates we find associated with fluid milks might be seen as counterintuitive as many analysts assert fluid milks are typically inelastic with respect to prices. We compared our results to those of Boehm and Babb (1975), who also noted the counterintuitive nature of their estimates. But using what they defined as a short-run analysis, they did find inelastic estimates. We hypothesize a similar analysis using the current data might lead to a similar result, but acknowledge that such work has not been done. This could be the focus of future research on the topic.

The cross-price relationships estimated in large demand systems provide information about how consumer preferences affect decisions to purchase (consume) one product as opposed to another. Such information can be of great importance to the dairy industry and retailers as they face decisions concerning which products to produce or how store operations might be affected as potential retail pricing decisions are considered. Some traditional and practical relationships exist and are expected among certain goods. For example, butter and margarine have been traditionally referred to as substitutes. It is expected that if the price of butter falls, then the demand for margarine will also fall.

Of the 240 compensated dairy product cross-price elasticities shown in Table 3, 225 (94%) are statistically significant at $P \leq 0.10$. Just to highlight a few cross-

price relationships, this study reveals that ice cream is a net substitute (i.e., the compensated cross-price elasticity is negative) for yogurt products; refrigerated yogurt is a net substitute for frozen yogurt, ice cream, and low-fat ice cream, and all fluid milk products are substitutes for themselves. Chouinard et al. (2010) also found whole milk to be a substitute for 1% milk, 2% milk, and no-fat milk, and ice cream a substitute for cooking and flavored yogurts (price elasticities of demand for dairy products are calculated at the sample means of the explanatory variables). Processed cheese, natural cheese, and cottage cheese are all net substitutes; creamer is a net substitute for fluid milk products; and butter and margarine are also net substitutes. Similar to our findings, Heien and Wessells (1990) found cottage cheese to be a substitute for other cheese products, and margarine a substitute for butter.

In addition to the substitution relationships, some interesting complementary relationships are worth mentioning. Ice cream is a net complement for low-fat ice cream, which means an increase in the price of ice cream will decrease the demand for low-fat ice cream. One possible explanation for this finding is that family members exist who prefer low-fat ice cream to regular ice cream. Frozen yogurt is found to be a net complement to refrigerated yogurt, cottage cheese, sour cream, creamer, and butter. Butter is a net complement to creamer and sour cream. One limitation of this study is that it is not possible to conclude with certainty that all cross-price relationships are decisions consumers will make at any given time, because of the fact that the data used for this analysis are purchase data. With

Table 3. Compensated price elasticities

Variable	Ice cream	Low-fat ice cream	Refrig. ¹ yogurt	Frozen yogurt	Whole milk	1% milk	2% milk	Skim milk	Canned milk	Natural cheese	Proc. ² cheese	Cottage cheese	Sour cream	Creamer	Butter	Marg. ³	Exp. elast. ⁴
Ice cream	-0.75*	-0.02*	0.12*	0.00*	0.04*	0.02*	0.05*	0.02*	0.01*	0.22*	0.07*	0.04*	0.04*	0.04*	0.11*	0.01*	1.08*
Low-fat ice cream	-0.02*	-1.20*	0.16*	-0.01	0.12*	0.12*	0.16*	0.17*	0.03*	0.13*	0.08*	0.06*	0.09*	0.06*	0.04*	0.00	0.97*
Refrigerated yogurt	0.15*	0.01*	-0.92*	-0.03*	0.07*	-0.01	0.23*	-0.11*	0.01*	0.18*	0.18*	0.00	0.04*	0.01*	0.07*	0.12*	0.92*
Frozen yogurt	0.13*	-0.01	0.02*	-1.18*	0.13*	0.09*	0.26*	0.19*	-0.02*	0.12*	0.16*	-0.01	0.02*	-0.06*	0.03*	0.16*	0.96*
Whole milk	0.08*	0.01*	0.17*	0.02*	-1.93*	0.28*	0.38*	0.38*	0.04*	0.24*	0.04*	0.10*	0.08*	0.06*	0.11*	-0.04*	0.79*
1% milk	0.08*	0.02*	0.02*	0.02*	0.37*	-1.73*	0.10*	0.15*	0.09*	0.21*	0.18*	0.13*	0.06*	0.10*	0.10*	0.11*	1.01*
2% milk	0.05*	0.01*	0.19*	0.04*	0.24*	0.03*	-1.60*	0.37*	0.04*	-0.27*	0.05*	0.09*	0.05*	0.05*	0.14*	-0.03*	1.08*
Skim milk	0.05*	0.03*	-0.12*	0.03*	0.42*	0.11*	0.59*	-2.30*	0.08*	0.29*	0.23*	0.14*	0.09*	0.12*	0.14*	0.12*	1.08*
Canned milk	0.10*	0.02*	0.09*	-0.03*	0.19*	0.31*	0.32*	0.37*	-1.32*	0.06*	-0.07*	0.04*	0.08*	0.08*	-0.15*	-0.07*	1.04*
Natural cheese	0.26*	0.00*	0.15*	0.00	0.16*	0.11*	0.35*	0.23*	0.00	-1.72*	0.26*	0.02*	0.00	0.03*	0.07*	0.08*	1.09*
Processed cheese	0.06*	-0.01*	0.22*	0.02*	-0.01	0.10*	0.03*	0.17*	-0.03*	0.28*	-0.90*	0.07*	0.01*	0.03*	0.07*	-0.08*	0.90*
Cottage cheese	0.16*	0.02*	0.00	-0.03*	0.20*	0.22*	0.32*	0.30*	0.02*	0.08*	0.18*	-1.71*	0.00	0.04*	0.08*	0.13*	1.12*
Sour cream	0.21*	0.06*	0.17*	-0.06*	0.25*	0.17*	0.30*	0.30*	0.06*	0.04*	-0.03	0.00	-1.33*	-0.04*	-0.11*	0.02*	1.06*
Creamer	0.30*	0.05*	0.17*	-0.08*	0.29*	0.33*	0.37*	0.46*	0.07*	0.22*	0.22*	0.09*	0.01	2.53*	-0.21*	0.26*	1.04*
Butter	0.32*	-0.01	0.14*	-0.02*	0.17*	0.13*	0.44*	0.26*	-0.09*	0.16*	0.16*	0.06*	0.07*	-0.17*	-1.78*	0.30*	1.05*
Margarine	0.07*	0.00*	0.15*	0.02*	0.02*	0.06*	0.07*	0.08*	0.00	0.15*	0.05*	0.05*	0.02*	0.03*	0.12*	0.89*	0.94*

¹Refrigerated.²Processed.³Margarine.⁴Expenditure elasticity.* $P < 10\%$ or better level of significance.**Table 4.** Estimated demographic marginal effects

Variable	Intercept	Children ages 6 and younger	Teenagers ages 13 to 17	Eastern region	Central region	Southern region	White HH ¹	Black HH	Asian HH	Single HH	Household income					
											≤\$19,999	\$20,000 to 34,999	\$35,000 to 49,999	\$50,000 to 69,999	\$70,000 to 99,999	\$100,000 to 149,999
Ice cream	-0.891*	-0.016*	-0.003*	0.005*	-0.012*	0.011*	0.069*	0.031*	0.006*	0.024*	0.023*	0.033*	-0.028*	0.021*	-0.018*	0.007*
Low-fat ice cream	-0.514*	-0.014	0.005	0.013*	0.021	0.005	-0.015	0.006*	0.004*	-0.027*	0.017*	0.026*	0.020*	0.014*	0.008*	0.004*
Refrigerated yogurt	0.998*	0.014*	-0.002	0.002	-0.020*	-0.039*	-0.136*	-0.009*	0.001	0.046*	-0.054*	-0.085*	0.073*	-0.062*	-0.043*	0.016*
Frozen yogurt	-0.019	-0.001	-0.001	0.001	-0.013*	-0.017*	0.087*	-0.009*	-0.000	-0.016*	-0.020*	-0.031*	0.023*	-0.026*	-0.019*	-0.010*
Whole milk	0.949*	0.030*	0.005*	0.022*	-0.021*	0.085*	0.187*	0.001	-0.001	0.043*	0.053*	0.062*	0.044*	0.028*	0.014	0.003
1% milk	-0.994*	0.000	-0.005*	0.027*	-0.050*	-0.015*	-0.030*	-0.016*	0.002*	0.029*	-0.006	-0.007	-0.001	-0.002	0.008*	0.003
2% milk	-1.195*	0.001*	0.017*	-0.025*	0.022*	0.048*	-0.123*	-0.017*	0.000	0.026*	0.040*	0.063*	0.051*	0.048*	0.029*	0.010*
Skim milk	-2.280*	-0.008	-0.008*	0.032*	0.011*	0.143*	0.209*	0.000	0.005*	0.066*	-0.027*	-0.023*	-0.018*	-0.014*	-0.005	0.002
Canned milk	0.561*	-0.014*	-0.008*	-0.025*	-0.011*	0.001	0.087*	0.036*	0.002*	-0.042*	0.011*	0.003	-0.001	0.006	-0.006	-0.004
Natural cheese	1.333*	0.006*	-0.003*	-0.031*	-0.055*	-0.106*	0.041*	-0.007*	-0.006*	0.007*	-0.030*	-0.033*	-0.023*	-0.014*	-0.009*	0.002
Processed cheese	0.480*	-0.003*	0.008*	0.016*	-0.058*	0.085*	0.089*	0.003*	-0.002*	-0.050*	0.022*	0.033*	0.031*	0.031*	0.023*	0.008*
Cottage cheese	0.154*	-0.016	-0.019*	-0.050*	0.003	-0.156*	0.126*	-0.035*	-0.005*	-0.006	-0.002*	0.012	-0.008	-0.009	0.047*	0.047
Sour cream	1.111*	0.005*	0.007*	-0.068*	-0.025*	-0.136*	0.047*	-0.023*	-0.007*	-0.047*	-0.043*	-0.065*	-0.046*	-0.037*	-0.028*	-0.011*
Creamer	0.813*	-0.016*	-0.015*	-0.093*	-0.046*	-0.111*	-0.041*	-0.028*	0.001	0.012*	-0.087*	-0.145*	-0.124*	-0.112*	-0.086*	0.037*
Butter	1.639*	-0.022*	-0.013*	0.001*	-0.076*	-0.215*	0.164*	0.034*	0.000	0.007	-0.070*	-0.110*	-0.089*	-0.072*	-0.053*	0.018*
Margarine	-0.065*	-0.002*	-0.001*	0.004*	0.010*	0.017*	0.014*	0.005*	-0.001*	0.019*	0.019*	0.027*	0.019*	0.014*	0.008*	0.002*

¹HH = head of household.* $P < 10\%$ or better level of significance.

purchase data, it is not possible to clearly determine what consumers ate as complements.

Expenditure elasticities are also presented in Table 3. All expenditure elasticities are statistically significant and positive, implying that the dairy products are normal goods. Ten of the 16 products have expenditure elasticities >1 , ranging from 1.01 for 1% milk to 1.12 for cottage cheese. Given the above findings, it is expected that a 1% increase in consumer household dairy expenditure for the observed products would boost the demand for nutritional products such as low-fat fluid milks and low-fat cheeses. Expenditure elasticities for products such as ice cream, cottage cheese, and butter are similar in magnitudes to those found by Heien and Wessells (1990; uncensored model), and the whole milk, yogurt and ice cream, and butter documented by Bailey (2009).

Estimated Elasticities of Demographic Variables

Table 4 displays the effect of demographic variables on the demand for at-home dairy products. Fifteen exogenous demographic variables are analyzed in the censored demand model, including children ages 6 and younger, teenagers ages 13 to 17, single head of household, individuals living in the Central, Eastern, and Western regions of the United States, black, Asian, and other races, and 6 household income categories ranging from 0 to \$149,999. Findings from the censored demand system show that purchases of whole and 2% milk products and sour cream are positively influenced by children ages 6 and younger and teenagers ages 13 to 17. However, in the cheese category, purchases of natural cheese are influenced by children ages 6 and younger, whereas purchases of processed cheese are influenced by teenagers ages 13 to 17. Of the 3 regions analyzed, more purchases of dairy products are influenced by purchasers from the East than any other region. Some of the products influenced by people residing in the East include ice cream, low-fat ice cream, whole, 1%, and skim milk, processed cheese, butter, and margarine. White people had the largest influence on product purchases and influenced the purchase of all 16 products except for low-fat ice cream, refrigerated yogurt, 1% and 2% milk, and creamer.

Single heads of household also played a significant role in the purchase of the 16 defined products. All fluid milks, excluding canned milk are influenced by single heads of household, along with ice cream, refrigerated yogurt, natural cheese, creamer, and margarine. Of the different demographic categories analyzed, the greatest influence on product purchases is household income. One of the most interesting findings concerning household income is that products such as low-fat

ice cream, whole and 2% milk, processed cheese, and margarine are all positively influenced by each one of the household income categories. Persons with household incomes ranging from \$0 to 34,999 are likely to influence the purchase of ice cream and low-fat ice cream, whereas yogurt purchases are influenced by persons with household incomes ranging from \$35,000 to 49,999. Cheese purchases are influenced mostly by persons with household incomes ranging from \$70,000 to 99,999. Butter and margarine purchases are influenced by persons with household incomes ranging from \$100,000 to 149,999. Given these findings, the overall influence of demographic variables on the purchase of the observed 16 products is substantial and should be seriously considered when estimating the demand for dairy products.

CONCLUSIONS

Economic analyses of systems of disaggregated dairy product demand provide insights on how changes in price, expenditure, and demographic variables affect purchases of the dairy products. The results presented here for 16 dairy product categories indicate that price, expenditure, and demographic factors are indeed important, with demographic factors having marginal, but statistically significant impacts. The analysis reveals a wide array of substitution and complementary effects between the individual products. Whether results of academic studies of food product demands inform decisions made by dairy product processors or manufacturers is a question we cannot answer. Arguably, such knowledge would be of interest to those companies, and to retail food outlet companies and milk producers as well. Having some ideas of how consumers might respond to dairy product price changes and what dairy products are considered to be substitutes or complements can enable dairy companies and retailers to devise production and marketing strategies to accommodate consumers' demand for dairy products. Findings from this study can help retailers coordinate grocery sales, bonus buys, and coupons to target specific dairy products when sales are low. As dairy companies and retailers respond to consumer actions, milk producers can continue to provide adequate milk supplies for alternative product markets.

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