International Food and Agribusiness Management Review
Volume 15, Issue 1, 2012

U.S. Fluid Milk Demand: A Disaggregated Approach

Christopher G. Davis[Φa], Diansheng Dong[b], Donald Blayney[c],
Steven T. Yen[d], and Richard Stillman[e]

[a]*Economist, Markets and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. 335 E. Street, S.W., Washington D.C., 20024, U.S.A.*

[b]*Economist, Food and Economic Division, Economic Research Service, U.S. Department of Agriculture, 335 E. Street, S.W., Washington D.C., 20024, U.S.A.*

[c]*Economist, Markets and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. 335 E. Street, S.W., Washington D.C., 20024, U.S.A.*

[d]*Professor, Department of Agricultural Economics, University of Tennessee, 308D Morgan Hall, 2621 Morgan Circle, Knoxville, Tennessee, 37996-4518, U.S.A.*

[e]*Economist, Markets and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. 335 E. Street, S.W., Washington D.C., 20024, U.S.A.*

Abstract

In this study, we examine retail fluid milk data from Nielsen 2007 Homescan. The objective of this study is to determine the impact of demographic variables, retail prices and total milk expenditure on flavored and non-flavored milk purchases. A censored AIDS model is used in estimate the demand for fluid milk. Results reveal that demographic variables have statistically significant impacts on fluid milk purchases, and own-price elasticities are unity or elastic for almost all fluid milk categories. All expenditure elasticities are unity or greater except whole milk and 1% milk.

Keywords: censored demand, fluid milk, Nielsen Homescan

[Φ]Corresponding author: Tel: + 1 202. 694.5167
Email: chrisdavis@ers.usda.gov
D. Dong: ddong@ers.usda.gov S. T. Yen: syen@utk.edu
D. Blayney: dblayney@ers.usda.gov R.Stillman: stillman@ers.usda.gov

Disclaimer: The opinions and analysis presented represent the authors' ideas and do not necessarily reflect those of Economic Research Service or the US Department of Agriculture.

Introduction

The milk industry faces a complex set of issues as it provides farm milk for the production of retail dairy products demanded by consumers. Having some assessment of the demographic and economic effects on milk and dairy product demands will allow both managers of retail outlets and dairy processors of milk and dairy products to develop more complete marketing and production strategies for their businesses.

Fluid milk is a major component of U.S. dairy consumption that has been widely studied by economists. The focus of this study is beverage fluid milk, not cream-based processed products such as half-and-half, sour creams, or drinkable yogurt. There is a long record of praise for the merits of milk and its products — not always derived from dairy cows — throughout the world. The role played by fluid milk products in promoting health, especially of young children, has long been emphasized. More recently, dairy products have been promoted as sources of vitamins and minerals that support bone health. However, not all discussions of milk products emphasize positive attributes. The dietary intake of fat, saturated fat in particular, in dairy products has been associated with risks of developing obesity, diabetes, and coronary heart disease (Frazao 1999). Positive and negative arguments aside, milk products are consumed and/or used as ingredients by most people on a daily basis.

Milk processors and suppliers in the U.S. have faced challenges over time, a major one being addressing concerns related to health and the consumption of milk fat. Changing consumption patterns among fluid milk products may have resulted in shifts in their demand functions, as shown in existing studies (e.g., Maynard 2000; Maynard and Liu 1999). In addition, existing studies have focused largely on aggregated fluid milk products, and such aggregation can mask changes in relative demand across fluid milk products at the retail level.

Figure 1 shows fluid milk sales by selected product categories from 1975 to 2009. The sales are defined in terms of gallons, the most frequently sold beverage milk container size and a more traditional way to think of liquid product measurement.

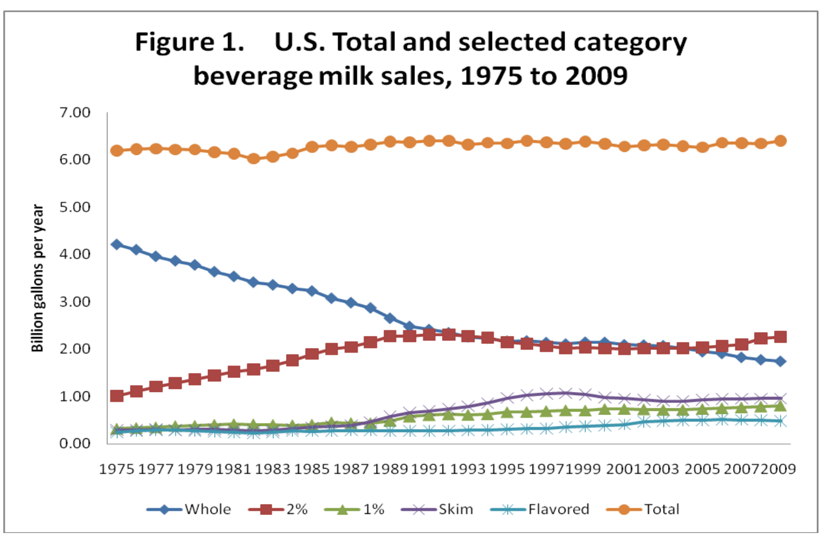

Figure 1. Beverage Milk Sales, 1979 – 2005.

Total fluid milk sales have been relatively stable over the 1975 - 2009 period at approximately 6,300 million gallons. However, whole milk sales declined over the period while sales of reduced-fat milks (2%, 1%, and skim) have mostly trended upward. A growing population over the 1975 – 2009 period combined with the relatively flat sales implies that the per capita total fluid milk demand have fallen. The aggregate trend masks an important point— total sales of reduced-fat milk products (the sum of 2%, 1% and skim milk) had been trending upward for some time but essentially leveled off beginning in 1991 then declining in 1996-97 and again leveled off around 2004. Flavored milk sales have more than doubled over the 25 years with a slight decline in 2009.

Numerous studies have examined the retail demand for fluid milk (Gould, Cornick, and Cox 1994; Gould and Lin 1994; Schmit et al. 2002; Dong and Kaiser 2005; etc.). However, this study differs from most fluid milk studies in that it includes demographic information for households that purchased flavored and non-flavored milk products. The objective of this study is to determine the impact that changing demographics, retail prices, and total milk expenditures have on flavored and non-flavored milk purchases.

The level of product disaggregation in this study allows for a more in-depth assessment of fluid milk demand. Using 2007 Nielsen data, competing products such as flavored and non-flavored whole, 2%, 1%, and skim milks are included in the analysis. Previous studies did not include all of these products. Because flavored milk products are a part of consumers' food basket, omitting them from the demand analysis may give rise to inaccurate estimations of consumers' demand for fluid milk. The factors affecting fluid milk demand are not static; therefore, periodic analysis of those factors is warranted given new product mixes and changing economic and demographic relationships. All nine disaggregated fluid milk elasticity estimates are important to the food industry. They can be used to enhance the ability of dairy industry and retail chain decision-makers to make more informed decisions about changes in fluid milk purchases.

The rest of the paper is organized as follows: a summary of related studies on the topic is presented, then a discussion of methods, data, empirical results, and concluding remarks.

Previous Studies of Demand Elasticities for Fluid Milk

Analysis of fluid milk demand has taken many forms and has revealed many factors that influence that demand. Early studies tended to identify milk as a single aggregate category, but as differentiated fluid milk types were produced, more data became available which allowed analysis of the set of differentiated products. While differences in packaging can be studied, the differences in demands for milks of varying fat content took—and still hold—center stage. This study identifies the gaps that exist in the dairy demand literature related to the number of fluid milk categories analyzed in previous studies, the lack of sufficient demographic information that measures the influence of non-economic factors, and the censored demand estimators used by other analysts.

Boehm and Babb (1975) published one of the earlier fluid milk demand studies that estimated consumer demand for four milk categories—whole milk, 2% milk, buttermilk, and canned milk. They used two models, the first was based on cross-sectional approach and the second was based on time-series approach. The empirical data used for the study was household panel data from the Market Research Corp. of America which was accessible by the United Dairy Industry Association for the time period April 1972 to April 1973. Using both Model A (cross-sectional data) and Model B (time-series data) to determine fluid milk demand, their findings showed that estimates from Model B were inelastic and less sensitive to changes in price than the estimates from Model A. While this study provides baseline elasticity estimates using cross-sectional data on fluid milk products, it fails to explore the availability of other competing disaggregated fluid milk products.

Gould, Cox, and Perali (1990) specified an almost ideal demand system (AIDS) model that included only two fluid milk products, whole milk and low fat milk. They examined change in fluid milk demand using time-series data from 1955 to 1985. Gould, Cox, and Perali (1990) provided historical estimates of whole and low fat milks that have been widely referenced by other studies. However, one of the shortcomings of this study is the aggregation of 2% milk, 1% milk, and skim milk into low fat milk, which overlooks and disregards the information that each disaggregated product provides. Another shortcoming is that the study did not show the impact that different non-economic factors have on fluid milk purchases.

In 1996, Gould again examined milk demand factors, but this time three categories were considered—whole milk, 2% milk, and combined 1%/skim milk. Nielsen Homescan data from April 1991 to March 1992 were used for the analysis. Gould's study was one of the first to provide elasticity estimates for 1%/skim milk. Similar to his earlier study, 1% milk and skim milk were combined, losing invaluable information that could have been used to measure consumers responsiveness to changes in the price and expenditure of 1% milk and skim milk separately.

Maynard and Liu (1999) investigated how demand for fluid milk products has become more elastic over time and, given the range of models available to derive elasticity estimates, evaluated the sensitivity of estimates to the type of demand model used. Their study made use of Nielsen retail scanner data from November 1996 through October 1998, and used three models to estimate own-price elasticities: the double-log, the static linear approximate AIDS (LA/AIDS), and the National Bureau of Research (NBR) differentiated models. Elasticity ranges across the models were the widest for the various milk types with the NBR model resulting in the most elastic estimates. This study does well in providing estimates using some of the most familiar methods utilized in the economic literature, but falls short in that it only has estimates for two types of fluid milk products, white milk and flavored milk.

Maynard (2000) and Chouinard, et al. (2010), estimated four fluid milk products, whole, 2%, 1%, skim or non-fat, using an AIDS model. Maynard (2000) study tested the hypothesis that less volatility of retail milk prices actually benefits consumers, while Chouinard, et al. (2010), determined how various demographic groups are affected by milk marketing orders. Although both Maynard (2000) and Chouinard, et al. (2010) examine all four types of white fluid milk products, their studies omit other fluid milk products such as flavored whole, 2%, 1%, and skim milks.

Akbay and Jones (2006) estimated demand elasticities and price-cost margin ratios for grocery products in different socioeconomic groups. They analyzed private and national branded items for lower and higher income stores using an AIDS model along with weekly store level scanner data for nine food categories from six supermarket chains in Columbus, Ohio from June 1998 through September 2000. Fluid milk is one of the dairy products analyzed. Their study analyzed the demand for fresh gallon milk (private), a half gallon milk (private), gallon milk (Sealest), and Nestle chocolate milk purchased at lower income stores. While the Akbay and Jones (2006) study does include flavored milk, it provides only the estimate of one flavored milk product, and it does not disaggregate fluid milk based on the different levels of fat content that are widely marketed in retail stores.

Another gap that exists in the literature is the lack of studies on non-economic factors that are closely related to fluid milk purchases. Purchases and/or consumptions of fluid milk products have been influenced by demographic factors as well. Gould, Cox, and Perali (1990) used data from 1955 to 1985 and found that children less than five years old, children from five years old to 13 years old, and the nonwhite population had a significant and positive coefficient for whole milk. Some of the non-economic or demographic factors that Gould, Cox, and Perali (1990) failed to include in their analysis were region and income. Regional and household income variables will help retailers target specific geographical areas and neighborhoods in the United States where fluid milk demand are highest.

Gould (1996) estimated a three fluid milk product demand system using weekly purchase data from April 1991 to March 1992. His findings showed that factors such as household composition, region of residence, ethnicity, income, and education had significant impacts on the demand for fluid milk. The use of household composition, region of residence, ethnicity, income, and education are important variables in any fluid milk analysis, but are incomplete in that they do not specifically account for children and teenagers in the home. Schmit and Kaiser (2004) estimated fluid milk elasticities and showed that income and children less than six years old had significant and positive elasticities for fluid milk. Similar to Gould, Cox, and Perali (1990), this study did not analyze the impact of geographic variables on fluid milk demand.

In addition to the studies mentioned, others have analyzed fluid milk products from different perspectives (e.g., Liu and Forker 1988; Gould, Cornick, and Cox 1994; Gould and Lin 1994; Schmit et al. 2002; Dong and Kaiser 2005). These analyses suggest that empirical estimates of the demand and expenditure elasticities are dependent on model specification. Like most of the analyses focusing on fluid milk in the literature, the majority of the studies mentioned used time series data created by aggregating weekly or monthly data. Such an approach circumvents problem of zero observations or purchases that are often encountered when using micro-level (household) data.

Many of the studies that used censored demand estimators have shortcomings. Some censored demand systems have problems with inconsistent estimates (Wales and Woodland 1983; Lee and Pitt 1986; Amemiya 1974; Ransom 1987), while other censored demand estimators have problems with satisfying the adding-up condition (Golan, Perloff, and Shen 2001; Yen and Lin 2006; Shonkwiler and Yen 1999; Sam and Zheng 2010; Perali and Chavas 2000; Meyerhoefer, Ranney, and Sahn 2005; Heien and Wessells 1990). Dong, Gould, and Kaiser (2004) implemented a mapping mechanism to achieve adding-up in the Tobit system of Amemiya (1974) that was suggested by Wales and Woodland (1983). This study utilizes the censored AIDS model developed by Dong, Gould, and Kaiser (2004).

The present study differs from other fluid milk demand studies in that it estimates the demand for white milk and flavored milk products using four different levels of fat content, whole, 2%, 1%, and skim. One other distinct difference is that this study includes several demographic variables that some fluid milk research studies omit such as the presence of children, teenagers, and elderly in the home, regional and ethnic or race variables, educational attainment, and household income level. And finally, this study satisfies the add-up conditions that other studies using censored demand analyses do not.

Methods

Because our data are censored, we used a censored demand system to estimate selected variables to avoid bias estimates. In demand system estimation with microdata, the most prominent statistical issue confronting analysts is censoring, or observed zero purchases, in the data. Such censoring has to be accommodated in order to obtain consistent parameter and elasticity estimates. Two challenges are usually involved in the estimation of a large censored demand system: imposing theoretical constraints among parameters and the evaluation of high order probability integrals. Among the various censored demand systems used in demand analyses, the Dong, Gould, and Kaiser (2004) approach is the one that satisfies the necessary adding-up condition. In this study, a censored AIDS model developed by Dong, Gould, and Kaiser (2004) is employed to derive elasticity estimates. The model estimation is an Amemiya-Tobin approach that imposes adding-up constraints on both latent and observed expenditure shares (Wales and Woodland, 1983). A simulated probability procedure is used in the model estimation to evaluate the high order probability integrals.

Following the method used by Dong, Gould, and Kaiser (2004), the AIDS model is defined based on the latent shares for K commodities as

$$(1)\quad Q^{*} = A + \gamma \ln P + \theta \ln Y + \varepsilon$$

where Q^{*} is a K-vector of latent expenditure shares on milk products, P is a K-vector of milk product prices, and $Y = y^{*} / P^{*}$ is the deflated total expenditures, with y^{*} is total expenditure, and P^{*} is the Translog price index, and ε is a K-vector of error terms. Household demographic variables are incorporated by transforming the intercept in (1). That is, the intercept is defined as $A = \alpha + \beta X$, where X is an N-vector of demographic characteristics. The parameters are α ($K \times 1$), β ($K \times N$), θ ($K \times 1$), and γ ($K \times K$).

Given the budget constraint, the latent shares must sum to one (adding-up). This adding-up condition can be attained through parametric restrictions. Other theoretical constraints such as homogeneity and symmetry can also be imposed on equation 1. The adding-up restriction implies that the joint density function of ε is singular. Consequently, one of the K latent share equations must be dropped during estimation. By dropping any equation from the estimation, it is assumed that the remaining $K - 1$ share equations' error terms, ε in equation (1), are distributed (K–1)-dimensioned normal with a joint probability density function.

As in all censored regression models, estimation of the model requires a mapping between the observed and latent dependent variable(s). In the present context, the mapping of the vector of latent shares (Q^*) to observed shares (Q) must take into account that the observed shares lie between 0 and 1 and also sum to unity for each observation. The following mapping rule imposes these two characteristics (Wales and Woodland, 1983)

$$(2)\quad Q_i = Q_i^* / \sum_{j \in \Omega} Q_j^* \quad \text{if} \quad Q_i^* > 0$$
$$= 0 \quad \text{if} \quad Q_i^* \leq 0,\ i = 1, 2 \ldots, K$$

where Ω is a set of all positive shares' subscripts. The way equation (2) maps Q^* to Q is simple and has the property that the resulting density function is independent of whatever set of elements in Q^*s is used in its derivation. By assuming that at least one milk product is purchased, one can write the likelihood function for each household according to its observed purchase pattern (regime). Consistent and efficient model estimates can be obtained by maximizing the sum of log likelihood function over all households. Since the likelihood function contains high order probability integrals, the simulated probability procedure is used in model estimation. Details can be found in Dong, Gould, and Kaiser (2004).

Elasticities are evaluated based on the expected expenditure share values. Expected values of observed expenditure shares can be obtained by summing the product of each regime's probability and the expected conditional share values over all possible regimes. Let C_s represent a particular purchase regime:

$$(3)\quad C_s = (Q_1 = Q_2 = \cdots = Q_s = 0; Q_{s+1} > 0, \cdots, Q_K > 0).$$

This is the regime where the first *s* shares are zero. Given these *s* zero-valued shares, other possible purchase patterns can be transformed to this pattern by rearranging the share ordering. Under this definition, regime *Cs* is actually the sum of all the purchase patterns with *s* zero-valued shares. The expected value of the *j*th observed expenditure share is

$$(4)\quad E(Q_j) = \sum_{s=1}^{K} \alpha_{C_s} E(Q_j \mid C_s)$$

where α_{C_s} is the probability that regime *Cs* occurs. The expected share value conditional on purchase regime *Cs* can be represented as

$$(5)\quad E(Q_j \mid C_s) = E[(Q_j^* \mid C_s) / \sum_{i=s+1}^{K} (Q_i^* \mid C_s)] \quad \text{if} \quad j > s$$
$$= 0 \quad \text{if} \quad j \leq s.$$

From (4) the impact of changes in prices, demographic characteristics and total expenditures on milk demand can be obtained, by evaluating *K*–1 dimension integrals. Given that there are 2^K–1 purchase regimes, one may need to evaluate these integrals a large number of times for a reasonably sized demand system. In this study, we follow Dong, Gould, and Kaiser (2004) to simulate the elasticities using the procedure developed by Phaneuf, Kling, and Herriges (2000) for a censored demand system applied to recreation choices. Thus, assume *C* replicates of the *K* error term vectors ε in equation 1. The *c*th simulated latent share vector, Q_c^*, evaluated at the sample means of our exogenous variables (indicated by a bar over a variable) is

$$(6)\quad Q_c^* = \alpha + \gamma \ln \bar{P} + \theta \ln \bar{y}^* / \bar{P}^* + \varepsilon_c$$

where ε_c is the cth replicate of ε. The cth replicate of the ith observed share then is

$$(7)\quad Q_{ic} = Q_{ic}^* / \sum_{j \in \Delta} Q_{jc}^* \quad \text{if} \quad Q_{ic}^* > 0$$

$$= 0 \qquad\qquad \text{if} \quad Q_{ic}^* \leq 0.$$

The expected observed share vector for C replicates is then calculated as a simple average of these simulated values:

$$(8)\quad E(Q) = \frac{1}{C}\sum_{c=1}^{C} Q_c.$$

Given a small change in price j, ΔP_j, the elasticity vector with respect to this price change is

$$(9)\quad \psi_j^Q = -\Lambda_j + \frac{\Delta E(Q)}{\Delta P_j} \times \frac{P_j + \Delta P_j / 2}{E(Q) + \Delta E(Q)/2}$$

where Λ_j is a vector of 0's with the jth element equal to 1, and $\Delta E(Q)$ is the change in the simulated $E(Q)$ given the change of price, ΔP_j. To derive elasticities for total expenditure and demographic variables we used:

$$(10)\quad \eta_j^Q = \frac{\Delta E(Q)}{\Delta Z} . \frac{1}{E(Q) + \Delta E(Q)/2},$$

where ΔZ denotes the change of total expenditure or demographic variables. Using the Slutsky's equation, the compensated elasticities are estimated by regular means.

Data

The data used in the analysis are 2007 household data provided by Nielsen Homescan. Based on the uniform product code and designated codes for each item, nine categories are considered: (1) whole milk, (2) 1% milk, (3) 2% milk, (4) skim milk, (5) whole flavored milk (6) 1% flavored milk, (7) 2% flavored milk, (8) skim flavored milk, and (9) other milk products (see Table 1 for sample statistics). The first eight categories are clearly fluid-milk beverage products. Other milk products consist of milk products that are labeled low-sodium, extra-rich, Passover, lactose, lactose-free, raw, goat milk, buttermilk, etc. There are 63,061 households that purchased at least one of the nine products in the 2007 data. Each purchase record is matched to a household record that contains information on the size and composition of the household, income, origin, age, race, gender, education and occupation of household members and market location. Information on head of household is provided based on gender, age, occupation, marital status and education. The head of household is self defined by the person participating in the survey and can be a single person or two persons, regardless of gender and marital and employment statuses. For an extensive discussion of the characteristics of the 2007 Nielsen Homescan data, see Zhen et al. (2009).

Quantities and expenditures are reported for all the nine products. Prices (unit values) are derived from observed quantities and expenditures after accounting for any coupons or promotions that might have been in effect. Prices used in this study are unit values. For households that purchased any of the products, we used the observed expenditures and quantities to calculate the unit values for each of the nine fluid milk products. For households that did not purchase any of the products, we estimated the unit values based on household variables. That is, we estimated a unit value equation for each of the nine products and used the predicted unit values for the missing prices. This is called first-order missing regressor procedure by Cox and Wohgenant (1986). In Table 1, there is information about the percentage of the 63,061 households that purchased each of the nine fluid milk products.

Summary Statistics

Based on the 2007 Nielsen Homescan data, consumers on average purchased more 2% milk and skim milk than they did any other non-flavored milk products (Table 1). Of the four flavored milk categories, consumers purchased more 2% flavored milk than they did any other. The highest average expenditures for non-flavored milk products are 2% milk ($32.85), followed by skim milk ($22.11). Among the flavored milks, expenditures are highest for 2% flavored milk ($1.05), followed by whole flavored milk ($1.01). The cost of fluid milk per ounce is not extremely different for whole milk, 1% milk, 2% milk, and skim milk. In contrast, there is more of a difference in the price of whole flavored milk and the other flavored milks. Table 2 shows the definitions and sample statistics of demographic variables used in the censored demand system. The demographic variables include one continuous variable, household size, and several dummy variables; including presence of children ages less than 6 years old in household, children ages 6 –12, and teenagers ages 13–17, male head age 65 years and older, females head age 65 years and older, Whites, Blacks, Asians, and Other race and ethnicity, Central, South, West, and East regions, female head of households with various levels education attainment[1] including college degrees, some college training, high school diploma only, and no high school diploma. In addition, there are seven different household income categories ($19,999 or less, $20,000–$34,999, $35,000–$49,999, $50,000–$69,999, $70,000–$99,999, $100,000–$149,999, and $150,000 or more). The variables Blacks, South, household income $20,000–$34,999, and female head of household with no high school diploma will serve as the base.

Results

Estimated Demand System Demographic, Price, and Expenditure Coefficients

Table 3 shows the coefficient estimates derived from a demand system consisting of nine different products and 21 demographic variables, a total of 189 demographic coefficients, nine expenditure coefficients, and 45 price coefficients. The system is estimated by programming the likelihood function in GAUSS. Of the 189 demographic coefficients, 112 are statistically significant at the one percent level, two at the five percent level, and 11 at the 10 percent level. All own-price coefficients are significant, and 34 of the 45 cross-price coefficients and eight of the nine expenditure coefficients are statistically significant. The next sub-sections present the price and expenditure elasticities, demographic elasticities related to the nine fluid milk products and the concluding remarks.

[1] The justification for using binary variables for education is to assess the impact educational attainment has on different types of milk purchases. Typically one would expect low fat milk purchases to be influenced by high educational attainments.

Table 1. Sample Statistics of Quantities, Expenditures, and Prices (Sample Size = 63,034)

Variable	Mean	SD	% Purchased
Quantities [e] (average gallons per household over 12 mo.)			
Whole	4.76	13.64	44
1 % milk	4.84	14.21	42
2 % milk	9.98	19.86	66
Skim	6.90	17.38	40
Whole flavored	0.18	1.40	11
1% flavored milk	0.18	1.66	06
2% flavored milk	0.26	2.08	09
Skim flavored milk	0.20	1.85	06
Other milk	0.11	1.78	03
Expenditures (average dollar spent per household over 12 mo.)			
Whole	16.91	45.93	
1 % milk	16.19	45.60	
2 % milk	32.85	61.93	
Skim	22.11	52.98	
Whole flavored	1.01	8.04	
1% flavored milk	0.76	6.80	
2% flavored milk	1.05	8.31	
Skim flavored milk	0.76	6.68	
Other milk	0.53	7.77	
Prices (average price paid per household over 12 mo.)			
Whole	3.55	0.009	
1 % milk	3.34	0.008	
2 % milk	3.29	0.010	
Skim	3.20	0.008	
Whole flavored	5.61	0.008	
1% flavored milk	4.22	0.010	
2% flavored milk	4.04	0.007	
Skim flavored milk	3.80	0.006	
Other milk	4.81	0.010	

[e] Fluid milk mean quantities were reported in fluid ounces and then converted into gallons. A gallon equals 128 fluid ounces.

Table 2. Definitions and Sample Statistics of Explanatory Variables

Variable	Definition	Mean
Continuous explanatory variables		
Household size	Number of members present in household	2.44
		(1.31) [a]
Binary explanatory variables (yes = 1; no = 0)	All binary variables are reported sample means.	
Young children	A child age < 6 present in household	0.09
Older children	A child age 6 -12 present in household	0.06
Teenagers	Teenagers in household ages 13 - 17 years old	0.13
Elderly Male	A Male in household age 65 and older	0.15
Elderly Female	A Female in household age 65 and older	0.17
Region		
Central	Household resides in the Central region of the U.S.	0.27
South [b]	Household resides in the Southern region of the U.S.	0.36
West	Household resides in the Western region of the U.S.	0.20
East	Household resides in the Eastern region of the U.S.	0.17
Educational level		
College degree	Female head has college education	0.34
Some college	Female head has some college education	0.29
High School diploma	Female head has a High School diploma	0.24
Less than High School [b]	Female head has no High School diploma	0.13
Race		
White	Head of household is Caucasian	0.84
Black [b]	Head of household is African-American	0.09
Asian	Head of household is Asian-American	0.02
Other race and ethnicity	Head of household is Other American	0.05
Household Income		
Income ≤ $19,999	Annual household income ≤ $19,999	0.11
Income $20,000–34,999 [b]	Annual household income $20,000–34,999	0.20
Income $35,000–49,999	Annual household income $35,000–49,999	0.19
Income $50,000–69,999	Annual household income $50,000–69,999	0.20
Income $70,000–99,999	Annual household income $70,000–99,999	0.18
Income $100,000–149,999	Annual household income $100,000–149,999	0.10
Income ≥ $150,000[b]	Annual household income ≥ $150,000	0.02

[a] Standard deviations in parentheses. [b] References category.

Table 3. Censored Demand System Parameter Estimates

Variable	East	Central	West	White	Other race and ethnicity	Asian	Children 5 years old and younger	Children ages 6 -12
Whole	–0.025***	–0.372***	–0.226***	–0.398***	–0.130***	–0.161***	0.296***	0.004
1% milk	0.279***	0.063***	0.192***	0.129***	0.011	0.101***	0.046***	0.049***
2% milk	–0.342***	0.108***	0.118***	0.044***	0.079***	0.071*	–0.188***	0.062***
Skim	0.024***	0.093***	–0.088***	0.208***	0.011	0.046	–0.168***	–0.178***
Whole flavored	–0.018***	0.020***	–0.056***	–0.010***	–0.001	–0.035***	0.001	0.008*
1% flavored milk	0.016***	0.014***	0.040***	0.016***	0.011**	0.006	0.002	0.017***
2% flavored milk	–0.007*	0.010***	–0.019***	–0.002	0.001	–0.011	0.011***	0.013***
Skim flavored milk	0.022***	0.015***	0.002	0.005*	0.004	–0.004***	0.002***	0.012***
Other milk	0.051***	0.049***	0.038*	0.007	0.013	–0.013	–0.001	0.014

Variable	Teenagers age 13-17	Males age 65 and older	Females age 65 and older	Household size	Female HH with college degree	Female HH with some college	Female HH with HS diploma	Income > $19,999
Whole	–0.083***	–0.032***	–0.133***	0.065***	–0.227***	–0.075***	0.001	0.259***
1% milk	0.060***	0.039***	0.079***	–0.047***	0.074***	0.024***	–0.014*	–0.135***
2% milk	0.119***	0.009	–0.011	0.071***	0.008	0.133***	0.203***	0.114***
Skim	–0.117***	0.050***	0.106***	–0.091***	0.131***	–0.110***	–0.214***	–0.222***
Whole flavored	0.007**	–0.021***	–0.017***	0.005***	–0.007***	0.005	0.008***	0.000
1% flavored milk	0.002	–0.008***	–0.009***	0.002	–0.006*	–0.001	–0.000	0.001
2% flavored milk	0.004	–0.015***	–0.014***	0.001	0.012***	0.018***	0.015***	–0.007***
Skim flavored milk	0.006*	–0.010***	0.008***	0.002*	–0.000	0.002	0.001***	–0.009***
Other milk	0.000	–0.011	0.008	–0.007	0.014	0.005	0.000	–0.001

Note: HH means head of household; and HS means High School.

Table 3. Censored Demand System Parameter Estimates (Continued)

Variable	Income $35,000 – 49,999	Income $50,000 – 69,999	Income $70,000 – 99,999	Income $100,000 – 149,999	Income ≤ $150,000
Whole	0.009	–0.122***	–0.178***	–0.228***	–0.282***
1% milk	0.014	0.051***	0.103***	0.131***	0.156***
2% milk	0.015	0.022***	–0.072***	–0.176***	–0.257***
Skim	–0.036***	0.053***	0.137***	0.268***	0.430***
Whole flavored	–0.010***	–0.011	–0.020	–0.031	–0.042
1% flavored milk	0.009***	0.001	0.008***	0.007*	0.013*
2% flavored milk	–0.004	–0.003	–0.004	–0.006	–0.009
Skim flavored milk	–0.002	–0.001	0.004	0.003	–0.006
Other milk	0.005	0.010	0.021	0.026	–0.003

Note: Asterisk *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Variable	Whole	1% milk	2% milk	Skim	Whole flavored	1% flavored milk	2% flavored milk	Skim flavored milk	Other milk
Expenditure coefficients	–0.05***	–0.02***	0.02***	0.00*	0.01***	0.01***	0.01***	0.01***	0.00
Price coefficients									
Whole	–0.67***								
1% milk	0.18***	–0.44***							
2% milk	0.14***	0.01***	–0.71***						
Skim	0.23***	–0.00	0.42***	–0.80***					
Whole flavored	0.05	0.05***	0.03***	0.03***	–0.09***				
1% flavored milk	0.00	–0.01***	0.09***	0.01**	–0.02***	–0.08***			
2% flavored milk	0.03	0.19***	–0.01***	–0.01***	–0.02***	0.01***	–0.16***		
Skim flavored milk	0.03***	0.04***	0.03***	0.03***	0.00	–0.04***	–0.03***	–0.03***	
Other milk	0.01	0.01	0.02	0.11***	–0.06***	0.00	0.01	0.01	–0.09***

Note: Asterisk *** indicates statistical significance at the 1% level, and * at the 10% level.

Table 3. Censored Demand System Parameter Estimates (Continued)

Variable	Whole	1% milk	2% milk	Skim	Whole flavored	1% flavored milk	2% flavored milk	Skim flavored milk	Other milk
Expenditure coefficients	–0.05***	–0.02***	0.02***	0.00*	0.01***	0.01***	0.01***	0.01***	0.00
Price coefficients									
Whole	–0.67***								
1% milk	0.18***	–0.44***							
2% milk	0.14***	0.01***	–0.71***						
Skim	0.23***	–0.00	0.42***	–0.80***					
Whole flavored	0.05	0.05***	0.03***	0.03***	–0.09***				
1% flavored milk	0.00	–0.01***	0.09***	0.01**	–0.02***	–0.08***			
2% flavored milk	0.03	0.19***	–0.01***	–0.01***	–0.02***	0.01***	–0.16***		
Skim flavored milk	0.03***	0.04***	0.03***	0.03***	0.00	–0.04***	–0.03***	–0.03***	
Other milk	0.01	0.01	0.02	0.11***	–0.06***	0.00	0.01	0.01	–0.09***

Note: Asterisk *** indicates statistical significance at the 1% level, and * at the 10% level.

There are two sets of demand elasticities derived from the censored demand models. The first is the uncompensated demand (Marshallian) elasticities. According to economic theory, the uncompensated demand curve does not allow income to change to account for any changes in price. The second set of elasticity estimates is called compensated (Hicksian) elasticities. Unlike uncompensated demand elasticities, the compensated demand elasticities do allow income to change to "compensate" for the price change. Policymakers may be most interested in knowing how much additional income support is needed to help a consumer purchase the same or comparable quantities of dairy products after prices increase. The uncompensated results show expenditure elasticities for identifying goods as normal, inferior, or luxury, which would be of interest to researchers. This is also a concern to retail store managers who are responsible for moving products into and out of their stores. Retail store managers would take an interest in consumers' responsiveness to changes in prices as well as changes in household expenditures – both will affect the quantity of products flowing into and out of retail stores.

Uncompensated Demand Elasticities

Estimates of the uncompensated price and expenditure elasticities are presented in Table 4. Consistent with theoretical expectations, all own-price elasticities are negative and statistically significant, –1.07 (the smallest) for other milk to –1.39 for 2% milk, –1.40 for 1% milk, –1.48 for whole milk, –1.94 for skim flavored milk, –2.39 for 1% flavored milk, –2.52 for whole flavored milk, –3.24 skim milk, and –3.82 for 2% flavored milk. All own-price elasticities for fluid milk are above unity in absolute value, which imply that a 1-percent change in price will cause an impact greater than 1-percent change in the quantity purchased of fluid milk. These empirical findings suggest that consumers are more sensitive to changes in fluid milk prices today than they were two or three decades ago.

For most fluid milk demand studies, elastic own-price elasticities may seem counter-intuitive because analysts typically view fluid milk prices as being inelastic. Boehm and Babb (1975) estimated fluid milk demand using two different models. One model used time-series model and data, while the other used cross-sectional model and data. The cross-sectional study yielded elastic own-price elasticities similar to the present study. Boehm and Babb suggested that their estimates were counter-intuitive. However, more and better substitutes for a product make the demand for that product more elastic. Previous studies disaggregated competing fluid milk into two, three, or four categories, while this study uses nine categories. As the products become more and more disaggregated, one would expect to find better substitutes and more elastic demands.

Estimates from this study, particularly the own-price elasticities for whole, 1% milk, 2% milk, and skim are similar to those reported by Boehm (1975), but larger than those estimated by Gould (1996). The own-price elasticity for flavored milk is more similar to estimates derived by Maynard and Liu (1999) and Akbay and Jones (2006). The findings from this study are important because they suggest to policymakers who are concerned about inducing calcium intake for specific segments of the population that changes in fluid milk prices will have a larger impact on quantity demanded.

As expected, there are many substitution relationships among the milk products, which support the conventional wisdom of consumers' purchasing behavior. Of the 72 cross-price elasticities, 67 are statistically significant. Forty-two of the uncompensated cross-price elasticities suggest substitute relationships among the fluid milk products. According to our findings, 1% milk serves as a gross substitute for all fluid milk products. Whole milk is also a gross substitute for 1% milk, 2% milk, skim milk, whole flavored milk, 2% flavored milk, and skim flavored milk. Likewise, skim milk is found to be a substitute for all fluid milk products except 2% flavored milk. The implications of these findings suggest that consumers will substitute one fluid milk product with another fluid milk product to satisfy changes in taste, health preference, or personal budget constraint. For example, results from this study suggest that consumers will purchase skim non-flavored milk if the price of skim flavored milk should increase, and vice versa. Consumers will also respond in a similar fashion if there are increases in the price of whole milk. Similarly, estimates by Gould (1996) showed that whole milk is a substitute for reduced-fat milk (2% milk), and skim milk. Retail managers may find these results useful as well as important in devising marketing strategies to increase fluid milk sales.

There are also statistically significant complementary relationships shown in Table 4. Twenty-five of the cross-price elasticities are negative and suggest complementary relationships. Just to highlight a few, whole milk is found to be a gross complement for 1% flavored milk and other milk products. Also, consumers are likely to purchase more 2% flavored milk given a reduction in the price of whole milk, 2% milk, skim milk, whole flavored milk, skim flavored milk and other milk.

Expenditure elasticities derived from the censored demand model are all positive and statistically significant (Table 4). Seven of the nine fluid milks have expenditure elasticities equal to or greater than 1. For six of those products, a 1-percent increase in total fluid milk expenditures will yield more than a 1-percent increase in the purchase of those fluid milk products. The implications of these findings are that as fluid milk expenditures rise the quantity demanded for six of the fluid milk products will increase by a percentage greater than the rise in expenditure. In this study, the expenditure elasticity estimates are similar to those reported by Gould (1996), who reported expenditure elasticities of 1.01 for whole milk and 2% milk and 0.98 for skim/1% milk. Policymakers may find these results important as they determine how they can increase supplemental payments to recipients of the Women, Infants, and Children program to boost intake of low fat fluid milk products.

Compensated Price Elasticities

Estimates of the compensated price elasticities are presented in Table 5. Similar to their uncompensated counterparts, all own-price elasticities are negative and statistically significant, implying an inverse relationship between the prices and quantities demanded of milk products. Also, both sets of own-price elasticities are elastic and suggest high consumer sensitivity to changes in fluid milk prices.

Compensated cross-price elasticity estimates display stronger net substitution relationships than net complementary relationships. Among the 61 statistically significant cross-price elasticity estimates, 46 suggest net substitutions and 15 suggest net complementary relationships. Consumers

Table 4. Uncompensated Price and Expenditure Elasticities

	Price of								
Product	Whole	1% milk	2% milk	Skim	Whole flavored	1% flavored milk	2% flavored milk	Skim flavored milk	Other milk
Whole	–1.48***	0.19***	0.14***	0.24***	0.01***	–0.02***	–0.01***	–0.01***	–0.03***
1% milk	0.20***	–1.40***	0.01***	0.05***	0.02***	–0.03***	0.16***	0.02***	–0.02***
2% milk	0.05***	0.02***	–1.39***	0.27***	0.01***	0.03***	–0.02***	0.00***	0.00
Skim	0.64***	0.03***	1.20***	–3.24***	0.07***	0.01	–0.06***	0.06***	0.30***
Whole flavored	0.50***	0.75***	0.42***	0.40***	–2.52***	0.34***	–0.28***	0.06	–0.89***
1% flavored milk	–0.15***	0.15***	1.55***	0.12**	0.37***	–2.39***	0.14***	–0.70***	0.02
2% flavored milk	0.30***	3.26***	–0.24***	–0.25***	–0.28***	0.16***	–3.82***	–0.54***	0.18**
Skim flavored milk	0.33***	1.06***	0.62***	0.68***	0.09	–1.07***	–0.92***	–1.94***	–0.22*
Other milk	–0.06***	0.03***	–0.01***	0.19***	–0.04***	–0.01***	–0.01**	–0.02***	–1.07***

Note. Asterisk *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level

Table 4. (Continued)

Product	Expenditure Elasticity
Whole	0.96***
1% milk	0.99***
2% milk	1.02***
Skim	1.01***
Whole flavored	1.23***
1% flavored milk	1.19***
2% flavored milk	1.23***
Skim flavored milk	1.37***
Other milk	1.00***

Note. Asterisk *** indicates statistical significance at the 1% level.

Table 5. Compensated Price Elasticities

Product	Price of Whole	1% milk	2% milk	Skim	Whole flavored	1% flavored milk	2% flavored milk	Skim flavored milk	Other milk
Whole	−1.28***	0.34***	0.51***	0.46***	0.02***	−0.02***	0.00	0.00	0.02***
1% milk	0.41***	−1.25***	0.38***	0.28***	0.03***	−0.02***	0.16***	0.02***	−0.01***
2% milk	0.27***	0.18***	−1.00***	0.50***	0.02***	0.04***	−0.01***	0.01***	0.00*
Skim	0.85***	0.18***	1.58***	−3.01***	0.08***	0.01	−0.06***	0.07***	0.31***
Whole flavored	0.75***	0.94***	0.88***	0.68***	−2.51***	0.34***	−0.27***	0.06	−0.88***
1% flavored milk	0.10*	0.03	1.99***	0.39***	0.38***	−2.38***	0.15***	−0.69***	0.02
2% flavored milk	0.56***	3.46***	0.23***	0.03	−0.27***	0.16***	−3.82***	−0.53***	0.18**
Skim flavored milk	0.62***	1.27***	1.13***	0.99***	0.11	−1.06***	−0.91***	−1.93***	0.22*
Other milk	0.15***	0.18***	0.37***	0.42***	−0.03***	−0.01***	0.00	−0.01***	−1.07***

Note. Asterisk *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level

Table 6. Estimated Marginal Effects for Demographic Variables

Variable	East	Central	West	White	Other race and ethnicity	Asian	Children 5 years old and younger	Children ages 6 -12
Whole	−0.001	−0.077***	−0.034***	−0.270***	−0.005***	−0.003	0.020***	0.001***
1% milk	−0.049***	0.018***	0.038***	0.099***	0.001***	0.002	0.005	0.004***
2% milk	−0.030***	0.016***	0.013***	0.011***	0.002	0.001*	−0.007***	0.003***
Skim	0.013***	0.072***	−0.050***	0.490***	0.001	0.003*	−0.037***	−0.028***
Whole flavored	−0.045***	0.088***	−0.181***	−0.144***	−0.001	−0.014***	0.003	0.008**
1% flavored milk	0.053***	0.070***	0.146***	0.235***	0.010***	0.002	0.005	0.019***
2% flavored milk	−0.015*	0.045***	−0.064***	−0.040	0.001	−0.005***	0.017**	0.014***
Skim flavored milk	0.110***	0.124***	0.009	0.126**	0.006	−0.003	0.006	0.020***
Other milk	0.007***	−0.001*	0.004***	−0.039***	0.000	−0.001***	0.004***	0.002***

Table 6. Estimated Marginal Effects for Demographic Variables (Continued)

Variable	Teenagers age 13-17	Males age 65 and older	Females age 65 and older	Household Size	Female HH with college degree	Female HH With some college	Female HH with HS diploma	Income > $19,999
Whole	–0.007***	–0.006***	–0.020***	0.131***	–0.063***	–0.015***	0.003***	0.023***
1% milk	0.008***	0.004***	0.012***	–0.102***	0.023***	0.009	–0.001	–0.014***
2% milk	0.008***	–0.001*	–0.003***	0.102***	–0.001	0.023***	0.029***	0.008***
Skim	–0.038***	0.021***	0.051***	–0.605***	0.126***	–0.091***	–0.147***	–0.069***
Whole flavored	0.014**	–0.056***	–0.052***	0.193***	–0.041***	0.024**	0.033***	0.000
1% flavored milk	0.004	–0.026***	–0.033***	0.088***	–0.040***	–0.005	0.000	0.002
2% flavored milk	0.010***	–0.043***	–0.045***	0.028	0.070***	0.092***	0.064***	–0.013**
Skim flavored milk	0.022**	–0.049***	–0.044***	0.135***	–0.001	0.017	0.006	–0.030***
Other milk	0.002***	–0.003***	–0.004***	0.026***	–0.008***	0.004***	0.007***	0.004***

Note. HH means head of household; and HS means High School.

Table 6. Estimated Marginal Effects for Demographic Variables (Continued)

Variable	Income $35,000 – 49,999	Income $50,000 – 69,999	Income $70,000 – 99,999	Income $100,000 – 149,999	Income ≤ $150,000
Whole	0.002*	–0.020***	–0.026***	–0.019***	–0.006***
1% milk	0.003*	0.009***	0.017***	0.012***	0.003***
2% milk	0.002*	0.001**	–0.008***	–0.011***	–0.004***
Skim	–0.020***	0.029***	0.069***	0.073***	0.031***
Whole flavored	–0.032***	–0.037***	–0.061***	–0.050***	–0.018***
1% flavored milk	0.033***	0.000	0.027***	0.012**	0.006**
2% flavored milk	–0.013*	–0.010	–0.014**	–0.003	–0.005*
Skim flavored milk	–0.008	–0.007	0.023*	–0.008	–0.005
Other milk	–0.002***	–0.003***	–0.003***	–0.003***	–0.002***

Note. Asterisk *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

respond most strongly to changes in prices for 1% milk as it relates to the demands for 2% flavored milk and skim flavored milk. A 1-percent decrease in the price of 1% milk will yield a 3.46% increase in the purchase of 2% flavored milk and 1.27% increase in the purchase of skim flavored milk. Also, a 1-percent reduction in the price of 2% milk and 1% flavored milk will give rise to purchases of skim flavored milk that exceed 1-percent. Like Maynard (2000), this study found whole milk to be a net substitute for 1% milk, 2% milk, and skim milks, as well as for the whole flavored milk and other fluid milk products. Cross-price elasticity estimates suggest that other fluid milk is a net complement to 1% milk and whole flavored. Similarly, skim flavored milk is a net complement to 1% and 2% flavored milks and other milk. Complementary relationships are found among flavored milks, which imply that consumers purchase both non-flavored and flavored milks and serve and/or consume them together.

Demographic Influence

Estimated demographic effects are presented in Table 6. A total of 21 demographic variables are included in the demand system. Several demographic variables have positive impacts on purchases of fluid milk products. Whole milk purchases are positively influenced by children ages 12 and younger, household size, female head of household with high school diploma, households earning less than $20,000 annually, and those earning $35,000 – $49,999. Gould, Cox, and Perali (1990) also found children ages 13 and younger to have a positive influence on whole milk purchases. Retail purchases of 1% milk are influenced positively by Whites and other races and ethnicities (of the heads of household), children ages 6 to 12, teenagers, males and females age 65 and older, female head of household with a college degree, households with income earnings of $35,000 and more, and people residing in the Central and Western regions of the United States. According to our findings, people residing in the Central and Western regions, children ages 6 to 12, teenagers, size of household, White heads of household, female head of household with some college experience and those with a high school diploma, and households with earnings less than $20,000 and those earning $35,000 to $69,999 annually positively influence the purchase of 2% milk. Demographic variables that positively influence purchases of skim milk include people residing in the Eastern and Central regions of the United States, White and Asian heads of household, male and female heads of household 65 years and older, females head of household with college degrees, and households with incomes of $35,000 and more annually.

Flavored milk products are also positively influenced by demographic variables. Of the four flavored milk categories, 1% flavored milk is influenced the most by demographic variables (Table 6). Purchases of 1% flavored milk are influenced positively by people residing in the Eastern, Central and Western regions of the United States, children ages 6 to 12, teenagers, size of household, White and of other race and ethnicity heads of household, and households with income earnings of $35,000 to $49,999 and $70,000 or more annually.

As displayed in Table 6, demographic variables have statistically significant impacts on fluid milk purchases. The demographic variables that have the broadest influence across most fluid milk categories are the Central region of the United States, children ages 6 to 12, teenagers, and household size. One reason the Central region has a positive effect on fluid milk purchases is that, on average, the Central region is an important dairy region that ranks in the top ten states in number of dairy animals and operations and raw milk production. What this finding suggests is that people in the Central region purchase more fluid milk products than people residing in the Southern region, which is the reference. Gould (1996) also found region of residence to have a positive influence on fluid milk purchases. This finding is important to retailers and dairy manufactures because it informs them where milk is most desired and where they can possibly increase sales.

It is no surprise that children ages 6 to 12 and teenagers influence the purchase of fluid milk products. For most American children and teenagers, milk is an essential food product in their diet. Reduced-fat fluid milk products are encouraged by the USDA food pyramid and the 3-Every-Day program as a source of vitamin D needed to help support strong bones and healthy diets. Gould, Cox, and Perali (1990) found that children less than 5 years old, children from 5 years old to 13 years old had a positive influence on whole milk, but a negative effect on low fat milk. Similarly, Schmit and Kaiser (2004) showed that children less than 6 years old had a positive impact fluid milk purchases. This finding is important and it conveys to retailers and dairy manufactures that their marketing strategies and commercials that emphasize the benefits of drinking milk are effective.

Household size is also expected to positively influence fluid milk purchases. Large households have more people, particularly more children present in the home. The more children present in the home the greater the demand for fluid milk. Most of previous studies have used the age of children present in the home as a proxy for household size. Household size is an important finding because it gives retailers and dairy manufactures a clear indication of whether there are households with no children that also impact fluid milk purchases.

Household income is also an important factor in determining the demand for fluid milk. In table 6, each of the seven-income categories shows some statistical significance for one or more fluid milk product. Households that earned $35,000 or more annually have a positive influence on the purchase of 1% milk, while households that earned $50,000 or more annually have a positive influence on the purchase of skim milk. Results also suggest that households whose total income is $70,000 or more annually have a positive impact on purchases of 1% flavored milk. Like this study, Schmit and Kaiser (2004) showed that household income had a positive influence on fluid milk purchases. This finding is important in that it gives retailers some insight on the type of fluid milk they should supply based on the average household income of the neighborhoods.

Closing Remarks

Many studies have reported estimates of demand elasticities for fluid milk products, but they have generally identified only a few product categories. In this study, the retail purchases of nine different fluid milk products: whole milk, 1% milk, 2% milk, skim milk, whole flavored milk, 1% flavored milk, 2% flavored milk, skim flavored milk, and a category of all other fluid milk products, are analyzed. The Nielsen Homescan data used for the analysis included many zero purchases, which present a complicated statistical problem in estimating the demand system. A censored demand system procedure is used to address this issue and to obtain statistically consistent estimates for demand parameters and elasticities.

Both uncompensated and compensated demand elasticity estimates are derived. Demographic variables are statistically significant and are found to affect demands for the nine fluid milk products. Findings also suggest notable differences between empirical estimates from the compensated and uncompensated demand specifications for the skim milk own-price elasticity. Our own-price elasticity estimates for whole milk and 2% milk are similar to those reported by Boehm and Babb (1975), but larger than those reported by Gould (1996). Uncompensated elasticity estimates suggest a mixture of both gross substitutions and complements, while the compensated elasticity estimates suggest that net substitutions are the more obvious pattern among the milk products.

Why do cross-price elasticities matter? If these estimates just remain on the pages of this article, they do not matter at all. Retail store managers would care about cross-price elasticities because changes in the price of one product may have implications for the demands, or quantities of the other products they are selling. If the retailer store managers under estimate supplies they need to move through their dairy cases, it will cost them extra to procure needed supplies. If they over estimate, then they will have to return unsold products to their suppliers, which would result in lost revenues. Policymakers would also have an interest in these cross-price elasticities. The substitutability of the differentiated fluid milk products allows a low fat fluid milk product to be exchanged for a fluid milk product that has a relatively higher fat content. Researchers or modelers will use these cross-price elasticities to analyze policy changes for the policymaker or forecast future market demands and conditions.

A disaggregated list of fluid milk price and expenditure elasticities can help retailers, dairy industry analysts, and policymakers understand how consumer purchases of individual product might change if product prices are contemplated. It assists them by providing a multiple product analysis, which allows one to examine the correlation or relationship between different products. For example, the disaggregated fluid milk elasticities from this study can inform retailers and dairy producers how consumers will likely respond if there is a change in the own-price of any one or more of the fluid milk products. If there is a 1-percent increase in the price of whole milk (for example), retail and dairy managers can expect the purchase quantity to decline by 1.48% (based on the uncompensated results) and the demand for 1% milk, 2% milk, skim milk, whole flavored milk, 2% flavored milk, and skim flavored milk to increase by 0.20%, 0.05%, 0.64%, 0.50%, 0.30%, and 0.33%, respectively.

The demand elasticities for the milk products are derived from the comparisons among prices and quantities purchased of the identified fluid milk products. Whole milk may be more elastic relative to the others since there are now several perceived substitutes to it that deliver the attributes consumers' desires. The own-price elasticities for whole milk have changed overtime. For a business selling all the products—decisions to raise or lower the prices of not just the elastic product but all the substitutes may be made with more of an eye toward how sales in total would be affected and thus the overall revenues to the seller. Raising the price of an elastic product is likely to have a greater effect on total milk sales than would a change in a less elastic product (since quantities of the less elastic would not change as much). Milk is desirable for most children and the elderly population because it provides calcium, a nutrient essential to proper health and development. However, whole milk and products made with whole milk have declined overtime partly due to the support of healthy diets and the push for low fat dairy products through programs like Women, Infants, and Children (WIC) and "3-Every-Day". A left shift in the demand curve for whole milk will cause both price and demand to fall, assuming all other things remain constant.

Assuming increases in consumers' food expenditures transfer into greater fluid milk expenditures, and given the estimated expenditure elasticities, it is expected that total fluid milk purchases also will rise. In particular, dairy producers and retailers may use these expenditure elasticities to estimate the impact increases or decreases in household expenditures may have on milk sales and dairy firm viability. A 1-percent increase in consumers' total milk expenditures will increase the purchase of 2% milk, skim milk, whole flavored milk, 1% flavored milk, 2% flavored milk, and skim flavored milk by more than 1-percent. All the expenditure elasticities suggest a positive effect on income in milk purchases. This study's expenditure elasticities for whole milk, 2% milk and 1% milk are similar to those reported in the literature (e.g., Gould, 1996).

Agricultural (dairy) product processors, manufacturers, and marketers or food retailers may use demographic information from studies to boost sales through advertisement of specific fluid milk products. For example, retail and dairy managers can use findings about the positive influence of factors such as children in the home, household size, female head of household with high school diploma, households earning less than $20,000 annually, and those earning $35,000 – $49,999 to help increase total sales of whole milk. It may be useful for retail and dairy managers to know that most fluid milk sales are positively influenced by teenagers, children ages 6 to 12, people residing in the Central region of the United States and large households. An increase in the Central region population will increase the demand for fluid milk. Over the next year, if there is an increase in household size, number of teenagers, or children ages 6 to 12 in America, we can expect the demand for fluid milk to increase also.

Selected household income categories have also had a positive influence on fluid milk consumption, particularly skim milk and 1% flavored and non-flavored milks. This information can be used by retail and dairy managers to increase sales through specific advertisements that target selected demographic group identified in this study. For example, the industry program "3-Every-Day", which is designed to encourage people to drink more low-fat milk, in addition to consuming more low-fat cheese and yogurt, developed several marketing programs directed toward children (National Dairy Council, 2011).

It has been suggested (Carman and Sexton, 2005) that fluid milk markets are vertically integrated from processors to retailers when the perspective is product costs but that at the retail level, estimates of demand relationships for fluid milk products are derived from a horizontally differentiated market. The information provided in this study can be useful to managers of both retail and dairy processing operations, but in different ways.

For the retailer, both demographic and economic information for specific locations is readily available from census and other sources. By analyzing this information to derive demand relationships such as price and demographic elasticities, retail managers can design specific pricing and promotional programs based on the demographic of the specific geographic locations of their stores. Since fluid milk generally has a short shelf-life product, the information provided in this study will also help retailers manage the dairy cases in their stores given the demographics of that store location.

The processors providing fluid milk products to determine retail customers can use information on how demand for those products relates to price or demographic factor changes to how much of each product might be made available. Milk is made up of fat, protein, and other solids in fixed proportions. As processors produce alternative final products, changing demands may force processors to find alternative markets for milk components. For example, if demand for lower fat fluid products grows, processors must find a use for the surplus fat in raw milk. This balancing of milk components may result in a fluid milk processor expanding his plant to include products such as ice cream, other cream products, and/or butter production.

References

Akbay, C. and E. Jones. 2006. Demand Elasticities and Price-cost Margin Ratios for Grocery Products in Different Socioeconomic Groups. *Agricultural Economics-Czech Academy of Agricultural Sciences* 52(2): 225–235.

Amemiya, T. 1974. Multivariate Regression and Simultaneous Equation Models when the Dependent Variables Are Truncated Normal. *Econometrica* 42(6): 999–1012.

Berndt, E., B. Hall, R. Hall, and J. Hausman. 1974. Estimation and Inference in Nonlinear Structural Models. *Annals of Economic and Social Measurement* 3: 653–665.

Boehm, T. William. 1975. The Household Demand for Major Dairy Products in the Southern Region. *Southern Journal of Agricultural Economics* 7(2): 187-196

Carman, H.F. and R.J. Sexton. 2005. Supermarket Fluid Milk Pricing Practices in the Western United States. *Agribusiness: An International Journal* 21(4): 509–530.

Chouinard, H.H., J.T. LaFrance, D.E. Davis, and J.M. Perloff. 2010. Milk Marketing Order Winners and Losers. *Applied Economic Review Perspective and Policy* 32(1): 59–76.

Cox, T.L. and M.K. Wohlgenant. 1986. Prices and Quality Effects in Cross-Sectional Demand Analysis. *American Journal of Agricultural Economics* 68(4): 908–919.

Deaton, A. 1988. Quality, Quantity, and Spatial Variation of Price. *American Economic Review* 78(3): 418–430.

Deaton, A. 1987. Estimation of Own- and Cross-Price Elasticities from Household Survey Data. *Journal of Econometrics* 36(1-2): 7–30.

Dong, D., B.W. Gould, and H. Kaiser. 2004. Food Demand in Mexico: An Application of the Amemiya-Tobin Approach to the Estimation of a Censored Food System. *American Journal of Agricultural Economics* 86(4): 1094–1107.

Dong, D., S. Shonkwiler, and O. Capps. 1998. Estimation of Demand Functions Using Cross-Sectional Household Data: The Problem Revisited. *American Journal of Agricultural Economics* 80(3): 466–473.

Frazao, E. 1999. High Costs of Poor Eating Patterns in the United States. America's Eating Habits: Changes and Consequences. *Agriculture Information Bulletin*, in U.S. Department of Agriculture, Economic Research Service. No. 750(April). Available online: http://www.ers.usda.gov/publications/aib750/aib750a.pdf

Golan, A., J.M. Perloff, and E.Z. Shen. 2001. Estimating a demand system with non-negativity constraints: Mexican Meat Demand. *The Review of Economics and Statistics* 83(3): 541–550.

Gould, B.W. 1996. Factors Affecting U.S. Demand for Reduced-Fat Fluid Milk. *Journal of Agricultural and Resource Economics*, 21(1): 68–81.

Gould, B.W., J. Cornick and T. Cox. 1994. "Consumer Demand for New Reduced-fat Foods: An Analysis of Cheese Expenditures." *Canadian Journal of Agricultural Economics* 42(4): 367–380.

Gould, B. W., T.L. Cox, and F. Perali. 1990. The Demand for Fluid Milk Products in the U.S.: A Demand Systems Approach. *Western Journal of Agricultural Economics*, 15(1): 1–12.

Gould, B.W. and H.C. Lin. 1994. The Demand for Cheese in the United States: The Role of Household Composition. *Agribusiness* 10(1): 43–57.

Heien, D., and C.R. Wessells. 1990. Demand Systems Estimation with Microdata: A Censored Regression Approach. *Journal of Business and Economic Statistics* 8(3): 365–371.

Lee, L., and M.M. Pitt. 1986. Microeconometric Demand Systems with Binding Nonnegativity constraints: The Dual Approach. *Econometrica* 54(5): 1237–1242.

Liu, D.J. and O.D. Forker. 1988. Generic Fluid Milk Advertising, Demand Expansion, and Supply Response: The Case of New York City. *American Journal of Agricultural Economics*, 70(2): 229–236.

Maynard, J. Leigh. 2000. "Empirical Tests of the Argument that Consumers Value Stable Retail Milk Prices." *Journal of Agribusiness* 18(2): 155–172.

Meyerhoefer, C.D., C.K. Ranney, and D.E. Sahn. 2005. "Consistent Estimation of Censored Demand Systems using Panel Data." *American Journal of Agricultural Economics* 87(3): 660–672.

Maynard, L.J. and D. Liu. 1999. Fragility in Dairy Product Demand Analysis. Paper presented at the annual meeting of the American Agricultural Economics Association, Nashville, TN., August.

National Dairy Council. Flavored milk provides nine essential nutrients advertorial and How to build a healthy kid back-to-school guidebook?

http://www.nationaldairycouncil.org/SearchResults/Pages/SearchResults.aspx?k=advertisement (Accessed March 11, 2011)

Perali, F., and J.P. Chavas. 2000. Estimation of Censored Demand Equations from Large Cross-Section Data. *American Journal of Agricultural Economics* 82(4): 1022–1037.

Phaneuf, D.J., C.L. Kling, and J.A. Herriges. 2000. Estimation and Welfare Calculations in a Generalized Corner Solution Model with an Application to Recreation Demand. *Review of Economics and Statistics* 82(1): 83–92.

Ransom, M.R. 1987. A Comment on Consumer Demand Systems with Binding Non-negativity Constraints. *Journal of Econometrics* 34(3): 355–359.

Sam, A.G., and Zheng, Y. 2010. Semiparametric Estimation of Consumer Demand Systems with Micro Data. *American Journal of Agricultural Economics* 92(1): 246–257.

Schmit, T.M., and H.M. Kaiser. 2004. "Decomposing the Variation in Generic Advertising Response Over Time." *Agricultural Journal of Agricultural Economics* 86(1): 139–153.

Schmit, T.M., D. Dong, C. Chung, H.M. Kaiser, and B.W. Gould. 2002. Identifying the Effects of Generic Advertising on the Household Demand for Fluid Milk and Cheese: A Two-Step panel Data Approach. *Journal of Agricultural and Resource Economics* 27(1): 165–186.

Shonkwiler, J.S., and S. T. Yen. 1999. Two-Step Estimation of a Censored System of Equations. *American Journal of Agricultural Economics* 81(4): 972–982.

Yen, S.T and A.M. Jones. 1997. Household Consumption of Cheese: An Inverse Hyperbolic Sine Double-Hurdle Model with Dependent Errors. *American Journal of Agricultural Economics*, 79(1):246–51.

Yen, S.T., and B. Lin. 2006. A Sample Selection Approach to Censored Demand Systems, *American Journal of Agricultural Economics* 88(3): 742–749.

Zhen, C., J., Taylor, M. Muth, and E. Leibtag. 2009. Understanding Differences in Self-Reported Expenditures between Household Scanner Data and Diary Survey Data: A Comparison of Homescan and Consumer Expenditure Survey. *Review of Agricultural Economics* 31(3): 470–492.

