The Demand for Fluid Milk Products in the U.S.: A Demand Systems Approach

Brian W. Gould, Thomas L. Cox, and Federico Perali

The demand for fluid milk products has changed dramatically in recent years not only in terms of lower levels consumed but also in terms of the composition of the products consumed. A time-series based demand system analysis of the market for lowfat and whole milk products is developed incorporating the effects of changes in prices and demographic characteristics. From the estimated model, the impacts of future changes in the demographic profile of the U.S. population on fluid milk demand are analyzed.

Key words: fluid milk demand, demand systems, demographic scaling.

The per capita consumption of fluid milk products has declined steadily over the last three decades from 291 pounds in 1966 to less than 236 pounds in 1987, a 19% decline. Coincident with this decline in overall fluid milk demand, there has occurred a change in demand away from whole milk beverage products towards reduced-fat milks such as lowfat and skim milk. Since 1966, lowfat milk consumption per capita increased from less than 34 pounds to more than 113 pounds in 1987 while the consumption of whole milk declined from 251 pounds to 110 pounds.[1]

Because of the change in fluid milk demand away from whole milk products, on a whole-milk-equivalent basis, the decline in milk consumption has been greater than the decline when measured on a product weight basis. Using per capita sales data, between 1954 and 1987 whole-milk-equivalent sales decreased by 36% while total product weight fluid milk sales decreased by 17%. From 1954 to 1965 whole milk accounted for more than 84% of whole-milk-equivalent sales while lowfat milk represented less than 3%.[2] By 1987, the consumption of lowfat milk had increased to the point where 27% of total fluid milk sales on a whole-milk-equivalent basis originated from the sale of lowfat milk, and only 55% of total sales originated from whole milk.

This trend of increased sales of lowfat milk products has not been limited to fluid beverage milk products. Over the last decade there have been increases in the consumption of lowfat cottage cheese, frozen desserts, and increased interest in reduced-fat cheeses. For example, in 1987 lowfat yogurt accounted for 73% of total U.S. yogurt production, compared with 10% for nonfat yogurt and 13% for fullfat. Three years earlier, lowfat yogurt accounted for 66%, nonfat 4%, and fullfat 30% of total production (Rogers).

The changing composition of dairy products to lowfat varieties has important policy implications both at the farm level as well as for

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[1] The generic term "lowfat milk" is used here to include buttermilk, lowfat flavored drinks, skim milk, and lowfat milk. For a more detailed discussion of the trends in per capita consumption of fluid milk products, refer to Haidacher, Blaylock, and Myers.

[2] The term "lowfat milk" in the context of the sales data includes lowfat and skim milk products only. Sales data were used in place of disappearance data because of detailed product differentiation.

the manufactured dairy product industries. For example, if the current milk pricing system were changed to one of multiple component pricing based on milkfat, protein, and/or solids-not-fat components, the value of milkfat might decline due to the increase in the demand for lowfat products. This decline in demand for milkfat might have the effect of increasing the supply of milkfat for use in other government-supported products such as butter. Currently there exist large surpluses of milkfat (*Cheese Reporter,* p. 1). Should the increased consumption of lowfat milk continue, such surpluses may increase and could have important ramifications in terms of the level of government subsidy payments required to maintain the price of milk and milk-based products. For example, recent increases in the federal dairy price supports stipulated an increase in the Commodity Credit Corporation (CCC) purchase price for nonfat dry milk while keeping the CCC purchase price of butter unchanged (*Dairy Market News,* p. 13).

The question remains as to the factors contributing to the increased consumption of lowfat milk and the impacts of continued change in these factors on the level of total milk demand, the demand for lowfat versus whole milk, and the intake of calcium, fat, and other nutrients. As noted by Raunikar and Huang; Heien and Wessells; and Haidacher, Blaylock, and Myers, changes in the types of milk products consumed have come about from a variety of sources including relative prices, incomes, and the demographic profile of the U.S. population.

The objective of the present study is to examine the impacts of changes in the demographic structure of the U.S. on the demand for fluid milk products, specifically the demand for whole versus lowfat milk. We first examine how such changes have affected milk demand over the last 30 years. We then use projections of future demographic changes to estimate how the demand for fluid milk products could change in the future both on a per capita basis and in terms of the overall market for fluid milk products. In order to achieve these objectives, we develop a demand model that specifically incorporates price and demographic variables. Unlike the cross-sectional studies of milk demand conducted by Huang and Raunikar; Blaylock and Smallwood; and Heien and Wessells, time-series data covering the period 1955–85 are used. An advantage of the use of time-series data is the inclusion of food-away-from-home (FAFH) consumption; in contrast, the cross-sectionally based analyses consider only food-at-home (FAH) consumption. Problems associated with the use of time-series data include collinearity among the independent variables and substantially fewer degrees of freedom.

Description of the Theoretical Model

In this study we assume that the consumer demand for milk and other food is the result of a two-stage budgeting process. First, the consumer determines the amount to spend on food. Then the consumer allocates this food budget among various food commodities. Given the econometric evidence provided by Heien and Wessells that first-stage food prices have little effect on second-stage food demand, we limit our analysis to the second stage. Because the focus of this study is on the demand for fluid milk products, we delineate four types of beverages and an aggregate "other food" category in the demand system.

The Almost Ideal Demand System (AIDS) model originally formulated by Deaton and Muellbauer is used in this analysis. This model is used due to the lack of a priori restrictions on the types of substitution characteristics that can exist among commodities and the exact aggregation properties of this functional form (Heien and Willett; Deaton and Muellbauer). The AIDS demand model can be obtained from the following expenditure function:

$$\ln M(U, P) = \alpha_0 + \sum_k \alpha_k \ln p_k + \tfrac{1}{2} \sum_k \sum_j \delta_{kj} \ln p_k \ln p_j + U^* \beta_0 \prod_k p_k^{\beta_k}, \quad (1)$$

where M is the minimum level of expenditure that is necessary to achieve utility level U^* given the vector of prices P which is composed of n individual commodity prices (p_k, $k = 1, \ldots, n$). If we let w_i represent the share of total expenditure associated with the ith commodity, the demand equations can be derived from equation (1) via Shephard's lemma and in budget share form appear as:

$$w_i = \alpha_i + \sum_j \delta_{ij} \ln p_j + \beta_i \ln(M/P') \quad (i = 1, \ldots, n), \quad (2)$$

where:

$$\ln P' = \alpha_0 + \sum_k \alpha_k \ln p_k + \tfrac{1}{2} \sum_k \sum_j \delta_{kj} \ln p_k \ln p_j. \quad (3)$$

The adding-up restrictions implied by economic theory can be represented by the following:

$$\sum_i \alpha_i = 1; \sum_i \delta_{ij} = 0 \quad (j = 1, \ldots, n); \text{ and } \sum_i \beta_i = 0. \quad (4)$$

In addition, for the demand functions to be homogeneous of degree zero in prices and income, it is necessary that:

$$\sum_j \delta_{ij} = 0 \quad (i = 1, \ldots, n). \quad (5)$$

Symmetry is satisfied if:

$$\delta_{ij} = \delta_{ji} \text{ for all } i, j \quad (i = j). \quad (6)$$

One of the traditional methods for incorporating demographic variables into demand systems is with equivalence scales. As noted by Lewbel, the problem with these variables is that they result in a very limited type of demographic effect where changes in demographic characteristics are virtually equivalent to changes in prices (p. 1). This restriction has been overcome through the use of demographic translating, scaling, and Gorman procedures. In this study, we use demographic scaling to overcome the shortcomings of demographic translating. Under translating, only the "subsistence" or "necessary" parameters of the demand system depend on demographic variables (Pollak and Wales 1981). If the original demand system can be represented by:

$$D_i = D_i(P, M), \quad (7)$$

demographic scaling replaces the original demand system by:

$$D_i = \phi_i D_i^*(p_1\phi_1, p_2\phi_2, \ldots, p_n\phi_n, M) = \phi_i D_i^*(p_1^*, p_2^*, \ldots, p_n, M), \quad (8)$$

where p_i^* are scaled prices (i.e., $p_i\phi_i$) and the ϕs are scaling parameters which are functions of the demographic variables, $s_1, \ldots, s_d$:

$$\phi_i = \phi_i(s_1, \ldots, s_d). \quad (9)$$

In the present study and similar to the specification used by Ray and by Barnes and Gillingham, the scaling function adopted is:

$$\phi_i = \prod_r s_r^{\epsilon_{ir}}, \quad (10)$$

where ϵ_{ir} is the estimated coefficient associated with the rth demographic variable in the ith scaling function.

Incorporating this scaling function into the AIDS share equations, equation (2) is reformulated to:

$$w_i = \alpha_i + \sum_j \delta_{ij} \ln p_j^* + \beta_i \ln(M/P^*) \quad (i = 1, \ldots, n), \quad (2')$$

where

$$\ln P^* = \alpha_0 + \sum_k \alpha_k \ln p_k^* + \tfrac{1}{2} \sum_k \sum_j \delta_{kj} \ln p_k^* \ln p_j^*. \quad (3')$$

With the incorporation of the scaling functions, the traditional homogeneity and adding-up conditions hold. In addition, equation (2′) must be homogeneous of degree zero in the original prices. This requires that equation (2′) must be homogeneous of degree zero with respect to the demographic variables. That is:

$$\sum_i \epsilon_{ir} = 0 \quad (r = 1, \ldots, d). \quad (11)$$

This normalization allows the identification of all the demographic parameters and guarantees that:

$$\sum_i \ln(\phi_i) = 0. \quad (12)$$

Equation (2′) is nonlinear in the parameters. Similar to previous studies that have incorporated demographic variables in demand systems, it is assumed that Stone's index provides an acceptable linear approximation to ln P^* (Capps, Tedford, and Havlicek; Heien and Wessells; Deaton and Muellbauer). That is:

$$\ln P^* \approx \sum_k w_k \ln p_k. \quad (13)$$

In order to avoid simultaneity problems, we adopt the Eales and Unnevehr approach where lagged share values ($w_{k,t-1}$) are used in equation (13).

A characteristic of the AIDS model is that both expenditure and price elasticities will change over time as the share of each commodity changes. Differentiating equation (2′), the expenditure (N_i), uncompensated price elasticities (Γ_{ij}), and compensated price elasticities (Γ_{ij}^*) are calculated via the following:

$$N_i = 1 + \beta_i/w_i, \quad (14)$$

(15) $\Gamma_{ij} = ((\delta_{ij} - \beta_i w_{j,t-1})/w_i) - K_{ij}$, and

(16) $\Gamma^*_{ij} = ((\delta_{ij} - \beta_i w_{j,t-1})/w_i) - K_{ij} + w_j[1 + \beta_i/w_i]$,

where K_{ij} is the Kronecker delta equal to one if $i = j$, zero otherwise.

Pollak and Wales (1980) show that the elasticity of the demand for the ith good with respect to the rth demographic characteristic (E_{ir}) is a function of the uncompensated own- and cross-price elasticities (Γ_{ij}) and the elasticity of the ith good's scaling function with respect to the rth demographic characteristic, Ω_{ir}:

(17) $$E_{ir} = \Omega_{ir} + \sum_j \Gamma_{ij}\Omega_{jr}.$$

Because the scaling functions vary across commodity type, the scaling functions can be interpreted to represent the number of commodity-specific "adult equivalents." We refer to these measures as "profile equivalents" in the present context as the demographic characteristics contained in the scaling functions contain more than just the number of children as in Pollak and Wales (1980) (e.g., number of adults older than 65, median number of years of schooling completed, percentage of the population that is nonwhite, etc.). Following Pollak and Wales (1981) and given equation (8), we can interpret preferences as depending not on the number of gallons of milk consumed but on the number of gallons per milk-equivalent profile, i.e., gallons/ϕ_i. The relevant price affecting consumption is not the price per gallon but the price per gallon per profile equivalent, i.e., $p_i\phi_i$.

Description of the Data and Estimation Procedures

Previous models of the demand for lowfat versus whole milk products have been developed using cross-sectional data. In this study we analyze the changes in demand using time-series data from 1955–85. Five commodities are delineated within the model: whole milk, lowfat milk, fruit juices, other nonalcoholic beverages, and other food.[3] In order to estimate the theoretical model, data are needed on the per capita quantities consumed and prices for each of these commodities. The demographic variables included in the demand model are: the proportion of the population less than five-years old (*POP*5); the proportion of the population between the ages of five and 13 years of age (*POP*513); the proportion of the population above the age of 65 (*POP*65); the proportion of the population that is nonwhite (*NONWHITE*); and the median number of years of schooling completed for those over 25 years of age (*SCHOOL*).[4]

The quantity data on whole and lowfat milk consumption were measured by per capita sales data obtained from Manchester, from Bunch and Simon, and from *Dairy Field*. Retail prices for whole milk, skim milk, and lowfat milk were obtained from published U.S. Bureau of Labor Statistics sources. Because a retail price series for lowfat milk was not available prior to 1980, an OLS regression between monthly retail skim milk and lowfat milk prices over the 1980–87 period was estimated.[5] Using the skim milk price series and the estimated regression, a lowfat milk price series was obtained.

Per capita juice and other beverage quantities consumed were estimated from various issues of U.S. Department of Agriculture (USDA) *Food Consumption, Prices, and Expenditures* (USDA 1968–85). Price series for the juice and other beverage commodities were estimated from the consumer price indexes for juice and nonalcoholic beverages, respectively, and calculated prices for these two commodity groupings were obtained from the 1965 USDA *Household Food Consumption Survey* (USDA 1968). Given the estimated prices and consumption levels for the four beverage com-

[3] In the estimated model, the lowfat milk categories include lowfat milk and skim milk. The "other beverages" category is composed of coffee, tea, and nonalcoholic carbonated beverages.

[4] Three age categories are used because of the unique nutritional requirements of the very old versus the very young segments of the population. We limited the number of age categories to three because of problems with degrees of freedom and collinearity. In earlier versions of the model, alternative age category groupings were used but resulted in statistically insignificant results.

[5] The final estimated equation used (with the coefficient standard error in parentheses) was:

$$LOWFATPR = 1.0754 \cdot SKIMPR$$
$$(.0033)$$

Std. Error of Est. = .027

Mean of *LOWFATPR* = 1.061

where *LOWFATPR* and *SKIMPR* are the monthly half-gallon prices of lowfat and skim milk, respectively. Earlier analyses allowed for an intercept term in the above equation but when used to estimate the price of lowfat milk out of the sample period, unrealistically high estimates were obtained and thus the intercept was omitted from the final regression.

modities, expenditures for "other food" were obtained by subtracting these expenditures from total food expenditures. The consumer price index for food was used as a proxy for the retail price of other food. Means of the independent variables and the associated correlation coefficients are presented in the appendix.

Because of the adding-up constraint, only four equations are independent. The other food equation is dropped from the estimation process. The parameters for this equation are estimated using the restrictions given in equations (4), (5), and (11). In order to estimate the parameters of the share equations that are invariant to the omitted share equation, the modified seemingly unrelated regression procedure suggested by Chavas and Segerson is used. With the use of demographic scaling, the estimated model is nonlinear in the parameters and thus is estimated using the SYSNLIN program within SAS. Demographic and price elasticities are calculated from the estimated coefficients and the predicted share values. For the demographic elasticities, approximate standard errors are computed via the δ-method described in Rao.

Empirical Model of Fluid Milk Demand

Table 1 presents the estimated coefficients for the demand system. All of the own-price coefficients are statistically significant at the 5% level. Seven of the 10 cross-price coefficients are also significant. The expenditure coefficients are significant at the 5% level except in the juice equation. From these coefficients compensated price elasticities are calculated (table 2). Fifteen of the 25 price elasticities are significant at the 5% level when evaluated at mean levels of the independent variables. All own-price elasticities are statistically significant at the 5% level.

Huang estimates that the uncompensated own-price elasticity for fluid milk products was −.259 based on a time-series demand systems model. Using this value and the relationship between compensated and uncompensated elasticities noted in Johnson, Hassan, and Green, the compensated elasticity from Huang is estimated to be −.351. In this study, the compensated own-price elasticities are −.324 and −.437 for whole and lowfat milk, respectively. In terms of the own-price elasticity of fruit juices, the present study finds a lower compensated elasticity value, −.327 versus −.490.

The cross-price elasticities between lowfat and whole milk show that they are substitute products, although the cross-price elasticities are not statistically significant. The cross-price elasticities between "other food" and whole milk, juices, and other beverages are statistically significant and indicate a substitution relationship. Similarly, the cross-price elasticities of juices and other beverages reflect a statistically significant substitution relationship.

Twenty-five demographic coefficients are estimated in the model. In table 1 we see that 11 of these coefficients are statistically significant. Five of these significant coefficients appear in the whole milk equation, and three are in the lowfat milk equation. None of the demographic coefficients are significant in the other food equation. The corresponding elasticities (see table 2) for the age structure variables indicate a major difference between the effects of these variables on whole versus lowfat milk demand.

The estimated relationship between age and the consumption of whole versus lowfat milk is different from previous cross-sectional analyses. Although not directly comparable to the present study, Haines, Guilkey, and Popkin in their cross-sectional analysis of women between the ages of 19–50 years show some similarity between age and the consumption of both types of milk. They found statistically significant negative relationships for those consumers who had positive levels of consumption. In contrast, in their tobit and probit analyses, the authors found significant negative relationships only in terms of the consumption of whole milk.

Huang and Raunikar using cross-sectional data in a tobit analysis of the consumption of lowfat and whole milk in the U.S. and for the South found differences between family life cycle and the consumption of these two types of milk. Raunikar and Huang in their analysis of the consumption of whole versus lowfat milk in the Northeast conducted a likelihood-ratio test of the null hypothesis that household expenditures for whole milk and lowfat milk were not related to family life-cycle stages. The results obtained by the authors suggested that the null hypothesis could be rejected for whole

Table 1. Estimated Coefficients of the AIDS Model

Dependent Variable	Independent Variables: Price — Whole Milk	Lowfat Milk	Juices	Other Beverages	Other Food	Expenditures
Whole Milk	.03165	−.00244	−.00229	.00139	−.02831	−.01731
	(.0042)	(.0019)	(.0013)	(.0014)	(.0057)	(.0065)
Lowfat Milk	−.00244	.00613	.00105	−.00246	−.00228	−.01042
	(.0019)	(.0021)	(.0006)	(.0007)	(.0032)	(.0033)
Juices	−.00229	.00105	.01459	−.00329	−.01006	−.01034
	(.0013)	(.0006)	(.0023)	(.0019)	(.0037)	(.0108)
Other Beverages	.00139	−.00246	−.00329	.06541	−.06105	−.04637
	(.0014)	(.0007)	(.0019)	(.0035)	(.0045)	(.0157)
Other Food	−.02831	−.00228	−.01006	−.06105	.10170	.08444
	(.0057)	(.0032)	(.0037)	(.0045)	(.0232)	(.0214)

Note: Asymptotic standard errors are presented in parentheses. *POP5* is a variable representing the proportion of the population less than five-years old, *POP513* is a variable representing the proportion between the ages of five and 13, and *POP65* is a variable representing the proportion above the age of 65. The variable *NONWHITE* represents the proportion of the population that is nonwhite. The median number of years of schooling completed for those over 25 years of age is represented by the variable *SCHOOL*.

milk but not lowfat milk (Raunikar and Huang, p. 57).[6]

In terms of the net effects of changes in the education level on demand, the results are consistent with previous cross-sectional analysis of the demand for whole milk products with whole milk demand being negatively affected by increased education levels. The differences observed between the lowfat and whole milk demand with respect to education levels may reflect the increased access to nutritional information and diet-conscious behavior associated with higher education levels (Huang and Raunikar, p. 30).

Previous analyses of the relationship between ethnicity and the consumption of milk products have not been consistent. In a tobit analysis conducted using the 24-hour individual food intake component of the 1977 USDA *Household Food Consumption Survey*, Haines, Guilkey, and Popkin found that Hispanic, black, and other nonwhite women tend to consume less lowfat milk than white women. The same was found for the consumption of whole milk products except for Hispanic women. A similar tobit analysis conducted by Haines, Guilkey, and Popkin using the 1985 USDA *Continuing Survey of Food Intake by Individuals* found insignificant ethnic coefficients for whole milk products. Huang and Raunikar using the 1977 USDA *Household Food Consumption Survey* found significant positive coefficients on a white household dummy variable in terms of lowfat milk but insignificant negative coefficients in the analysis of the demand for whole milk products. Table 1 shows that a significant and positive coefficient for *NONWHITE* was obtained in the whole milk equation while a negative but insignificant coefficient was obtained in the lowfat milk equation. The differences between the results obtained here and those in previous cross-sectional studies may be due to the fact that the variable *NONWHITE* encompasses Hispanics and blacks as well as other minorities.

The Impacts of Projected Changes in Demographic Characteristics on Fluid Milk Demand

With the above elasticity estimates, we can examine the implications of future changes in the characteristics of the U.S. population for fluid milk demand. Following Theil; and Heien and Wessells, the predicted quantities of lowfat and whole milk consumption can be calculated as:

$$\ln q^p_{it} = \sum_j \Gamma_{ij} \ln P_{jt} + \sum_r E_{ir} \ln s_{rt} + N_i \ln M_t, \quad (18)$$

[6] We examined the impact of including a time-trend variable in the share equations on the sign and significance of the demographic variables. Inclusion of the time trend did not change the sign nor significance of any of the demographic variables that were significant in the original system nor did it change the significance level of those demographic variables that were not significant. The magnitudes of the coefficients were not affected appreciably.

Table 1. Continued

Independent Variables								
Demographic Variables								
POP5	*POP513*	*POP65*	*NONWHITE*	*SCHOOL*	Intercept	RMSE	R^2	D.W.
2.1520 (.6286)	1.2029 (.3905)	−2.1120 (.6571)	.79078 (.3788)	−1.3838 (.5196)	.11042 (.0494)	.0007	.999	2.366
−2.9113 (1.549)	−1.6647 (.7712)	2.1093 (1.426)	−.23338 (.7236)	3.3338 (1.075)	.08468 (.0275)	.0003	.997	2.300
−.42329 (.6522)	.10358 (.4769)	.44557 (.9626)	−.46422 (.8004)	−2.3639 (.8711)	.21623 (.0804)	.0011	.806	1.943
.65438 (.2630)	−.07230 (.1873)	−.09482 (.3816)	.05419 (.3003)	.75088 (.3378)	.20386 (.1126)	.0017	.990	1.614
.52821 (2.545)	1.08117 (1.410)	−.34805 (2.638)	−.14737 (1.655)	−.33698 (2.124)	.38481 (.1602)			

where q^p_{it} is the predicted level of the ith commodity in the tth period. Using this equation, the annual compound rate of growth between two periods can be estimated as:

$$R_i = 1/T\left[\sum_j \Gamma_{ij}(\ln P_{jt} - \ln P_{jt-T}) + \sum_r E_{ir}(\ln s_{rt} - \ln s_{rt-T}) + N_i(\ln M_t - \ln M_{t-T})\right], \quad (19)$$

where R_i is the annual compound rate of growth for the ith commodity between two periods T years apart. In the present analysis we are concerned only with the future impacts of changes in the demographic variables. As such, in equation (19) the changes in prices and income are assumed to be zero. Projections for changes in the variables *POP5*, *POP513*, *POP65*, and *NONWHITE* over the 1990–2010 period were obtained from Spencer. Projections for changes in the median number of years of school completed were obtained from the following regression equation estimated using a GLS estimator to correct for autocorrelation over the 1950–85 period (with coefficient standard errors in parentheses):

$$\ln(SCHOOL) = \underset{(.0228)}{2.2311} + \underset{(.0079)}{.0819}\ \ln(TIME) + \underset{(.0857)}{.8617}\ e_{t-1}$$

$$D.W. = 2.189 \qquad \bar{R}^2 = .952$$

where *TIME* was set equal to one for 1950.

Table 3 presents the decomposition analysis for whole and lowfat milk for the years 1985–2010.[7] For example, over the 1985–2010 period, the annual rate of change in the per capita demand for whole milk demand resulting from changes in the proportion of the population less than five years of age is projected to be −.81% per year. This is the product of the elasticity of whole milk demand with respect to *POP5* (.90%) and the annual rate of change of this variable (−.91%). The "ALL AGE" column in this table shows the total impact of changes in the age structure of the population on fluid milk demand, while the last column shows the annual rate of change in milk demand resulting from projected changes in the five demographic characteristics.

Over the 25-year period, changes in the age structure are projected to cause an average annual decline in whole milk consumption of 1.66%. This trend is projected to increase over time from an annual rate of −1.32% over the 1985–90 period to −1.84% over 1995–2000. In contrast, a positive growth rate resulting from changes in the age structure is projected for lowfat milk, increasing from an annual growth rate of 1.32% over the 1985–90 period

[7] As noted by a reviewer, the following analysis implicitly assumes that the demographic coefficients remain stable over the projection period. An area for further study would be to use a varying coefficients model to allow for these coefficients to change over time. Moschini and Meilke develop a varying coefficients model that may be useful for these purposes.

Table 2. Compensated Own- and Cross-Price, Expenditure and Demographic Elasticities

Dependent Variable	Price					Expenditures	Demographic Variables				
	Whole Milk	Lowfat Milk	Juices	Other Beverages	Other Food		*POP5*	*POP513*	*POP65*	*NON-WHITE*	*SCHOOL*
Whole Milk	−.324	.059	−.023	.119	.168	.658	.897	.384	−1.015	.603	−.357
	(.090)	(.038)	(.025)	(.028)	(.099)	(.114)	(.667)	(.310)	(.397)	(.631)	(.762)
Lowfat Milk	.270	−.437	.117	−.130	.180	.062	−1.660	−.907	.988	.084	1.364
	(.175)	(.218)	(.057)	(.062)	(.287)	(.211)	(.407)	(.291)	(.276)	(.440)	(.511)
Juices	−.051	.058	−.327	−.055	.376	.539	−.964	−.316	.774	−.335	−1.200
	(.059)	(.029)	(.146)	(.088)	(.150)	(.412)	(.202)	(.101)	(.129)	(.196)	(.191)
Other Beverages	.066	−.016	−.014	−.193	.156	.492	.242	−.280	.060	.172	.738
	(.015)	(.008)	(.021)	(.052)	(.056)	(.146)	(.248)	(.117)	(.121)	(.222)	(.225)
Other Food	.010	.002	.010	.017	−.040	1.102	−.033	.028	.021	−.048	−.046
	(.007)	(.004)	(.005)	(.007)	(.011)	(.024)	(.034)	(.016)	(.017)	(.031)	(.033)

Note: Approximate standard errors are presented in parentheses. Refer to table 1 for definitions of the demographic variables.

to 3.55% during 1995–2000 with a 25-year average growth rate of 2.63%.[8]

Blaylock and Smallwood in their analysis of the impacts of demographic changes on food demand found that changes in the age distribution had very little impact on per capita fluid dairy (milk and cream) demand over the 1980–2010 period. The differences between their results and those of the present study may be due to: their use of cross-sectional versus time-series data, their aggregation of lowfat and whole milk demand, their inclusion of fluid milk products not incorporated in this study, and their analysis of at-home fluid milk consumption versus aggregate (FAH and FAFH) sales.

Future changes in the proportion of the population that is nonwhite and the median number of school years completed are estimated to have relatively minor impacts on fluid milk demand. The projected annual rates of change of per capita whole milk demand due to the projected changes in the variable *NONWHITE* decrease from .62% over 1985–90 to .49% over 2005–10. For lowfat milk, the rates of change decrease from .09% for 1985–90 to .07% for 2005–10. In terms of the effect of future changes of the variable *SCHOOL*, the annual percent decrease in per capita whole milk demand is projected to be less than .07% for all years analyzed.

Table 3 summarizes the annual growth rates (on a per capita basis) for the effects of changes in the demographic characteristics included in this study. Adding these annual growth rates to the projected population growth rates yields an estimate of the demographically induced changes in the total demand for lowfat and whole milk (table 4). Total population estimates over the 1985–2010 period were obtained from Spencer.[9] Using the procedure outlined by Theil, the annual compound population growth rate is projected to decline from .91% over the 1985–90 period to .50% over

[8] Given the uncertainty with respect to future prices, this analysis is undertaken with observed prices held constant at 1985 levels. With increased consumption of lowfat milk products, the milkfat that was previously contained in whole milk sales could be used in the production of other dairy products. This reallocation may have substantial effects on the relative prices of both fluid and nonfluid dairy products. In the present analysis we are only concerned with examining the impacts of changes in demographic characteristics on fluid milk demand.

[9] These population projections are based on the Middle Series in order to be consistent with the demographic changes analyzed previously. Refer to Spencer for a discussion of the assumptions associated with the Middle Series.

Table 3. Decomposition of Projected Annual Rates of Change in the Demand for Whole Milk and Lowfat Milk, 1985-2010

Year	*POP5*	*POP513*	*POP65*	All Age	*NON-WHITE*	*SCHOOL*	All Demo
				(%)			
Whole Milk							
1985–1990	−.360	.202	−1.165	−1.323	.616	−.011	−.718
1990–1995	−1.287	.048	−.597	−1.836	.563	−.067	−1.340
1995–2000	−1.484	−.323	−.037	−1.844	.549	−.060	−1.356
2000–2005	−.792	−.559	−.247	−1.597	.528	−.055	−1.124
2005–2010	−.140	−.430	−1.151	−1.721	.493	−.050	−1.278
1985–2010	−.813	−.212	−.639	−1.664	.550	−.049	−1.163
Lowfat Milk							
1985–1990	.666	−.477	1.134	1.323	.086	.043	1.452
1990–1995	2.382	−.115	.581	2.849	.078	.257	3.184
1995–2000	2.745	.764	.037	3.546	.076	.231	3.853
2000–2005	1.465	1.321	.240	3.027	.073	.209	3.309
2005–2010	.260	1.017	1.121	2.398	.069	.191	2.658
1985–2010	1.504	.502	.623	2.629	.076	.186	2.891

Note: Refer to table 1 for definitions of the demographic variables.

the 2005–10 period. Over the entire 25-year period, the annual growth rate is projected to be .67%.

The projected change in the total population reinforces the projected increase in the per capita demand for the lowfat milk market and reduces the negative impacts of lower per capita consumption of whole milk. The overall demand for whole milk is projected to increase over the 1985–95 period. Over the 1985–2010 period, total whole milk demand is projected to decline at an annual compound rate of .50% while lowfat milk is projected to increase at an annual rate of 3.56%.

The importance of the population increase on overall changes in the demand for lowfat milk diminishes over the 1985–2010 period. The last column in table 4 shows the ratio of the annual rate of population growth to the growth in lowfat milk demand. This ratio decreases from .385 over the 1985–90 period to .138 for 1995–2000 and remains relatively constant over the remaining simulation period. The average ratio over the 25-year projection period is .187. Again, these results assume that the demographic effects (i.e., estimated coefficients) do not change over the forecast period.

Conclusions

Changes in the demographic profile along with increased purchasing power have been identified as having important implications for future food consumption patterns. The present study develops a demand system incorporating demographic variables so as to better understand the current structure of the demand for fluid milk products and the implications of projected changes in the demographic characteristics of the U.S. on fluid milk demand. Such a model is important both to the development of agricultural policy as well for the development of marketing strategies associated with these commodities. With recent increases in both generic and brand-specific ag-

Table 4. Projected Annual Compound Population Growth Rates and the Impacts on Overall Milk Demand

Period	Project. Pop. Growth Rate	Total Demand Change: Whole Milk	Total Demand Change: Lowfat Milk	Pop. Growth/ Total Lowfat
	(%)	(%)	(%)	
1985–1990	.909	.191	2.361	.385
1990–1995	.762	−.578	3.946	.193
1995–2000	.615	−.741	4.468	.138
2000–2005	.540	−.584	3.849	.140
2005–2010	.500	−.778	3.158	.158
1985–2010	.665	−.498	3.556	.187

Note: The changes in total demand are due to changes in demographic characteristics and in the size of the population. The above results are conditional on 1985 actual prices and total food expenditures in that the impacts of changes in relative actual prices or changes in total food expenditures have not been incorporated.

ricultural commodity promotion, knowledge as to the impacts of demographic characteristics are essential to the appropriate segmentation of the population to target such promotion activities.

The results from the demand system estimation are used to estimate changes in the overall market demand for whole milk and lowfat milk products over the years 1985–2010 resulting from changes in the demographic characteristics of the U.S. The results obtained point to an average annual increase in per capita lowfat milk consumption of 3.6% and a decrease in whole milk consumption of .5%. These results are important given recent debates with respect to changes in the 1985 Food Security Act and the Federal Milk Marketing Orders (General Accounting Office; McDowell, Fleming, and Fallert). Policy makers must take into consideration the increased supply of milkfat that may be generated, and any modification to the methods used to determine milk prices should take into account anticipated demand shifts caused by changes in the population's demographic profile.

This study has been concerned with an analysis of fluid milk demand. From an agricultural policy perspective, it is essential to understand what factors are affecting the utilization of milk in all of its forms. An area of future research would include an analysis of the effects of changes in demographic characteristics on the demand for manufactured dairy products. This is important due to a unique situation facing the dairy industry. While there has been a reduction in the demand for high-fat fluid milk products, the consumption of relatively high-fat cheese products has been increasing as shown by the increase in the per capita consumption of whole and part-whole milk cheeses from 9.7 to 24.0 pounds over the period 1966–87 (Putnam). Such trends suggest significant differences in the role of demographic and price variables in the demand for fluid milk versus manufactured dairy products.

Heien and Wessells present a model that investigates the demand for a variety of dairy products but use aggregated commodity categories and limit the demographic effects to the intercept terms of the share equations. In order to identify the unique trends associated with specific types of milk-based products, the analysis conducted in the present study should be expanded to a larger number of dairy commodity categories and alternative methods for measuring demographic effects in demand systems should be incorporated and evaluated.

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Appendix

Table A1. Means of Dependent and Independent Variables and Descriptive Statistics

Variable	Units	Mean	Coefficient of Variation	Minimum	Maximum
Prices					
Whole Milk	$/.5 gal.	.677	.399	.387	1.222
Lowfat Milk	$/.5 gal.	.642	.393	.385	1.079
Juices	$/pound	.356	.419	.207	.742
Other Beverages	$/gal.	.871	.682	.400	1.991
Other Food Index	—	1.534	.508	.816	3.098
Total Food Exp.	$	777.5	.582	351.8	1,760.5
Demographic Variables					
POP5	%	9.074	.185	7.1	11.3
POP513	%	16.426	.128	12.6	18.7
POP65	%	10.023	.105	8.5	11.9
NONWHITE	%	12.858	.122	10.7	15.4
SCHOOL	years	11.871	.060	10.4	12.6

Note: Refer to table 1 for definitions of the demographic variables.

Table A2. Pearson Correlation Coefficients for Price and Demographic Variables

	Prices					Demographic Variables					
	Whole Milk	Lowfat Milk	Juices	Other Beverages	Other Food	*POP5*	*POP513*	*POP65*	*NONWHITE*	*SCHOOL*	*EXPEND*
Whole Milk	1.000	.9899	.8665	.9485	.9918	−.9219	−.9258	.9780	.9539	.8406	.9071
Lowfat Milk		1.000	.8599	.9565	.9919	−.9203	−.9440	.9698	.9539	.7959	.8812
Juices			1.000	.9010	.8952	−.6642	−.8898	.8620	.7871	.6452	.7105
Other Beverages				1.000	.9733	−.8314	−.9799	.9200	.8993	.6856	.7955
Other Food					1.000	−.8973	−.9592	.9743	.9486	.7965	.8835
POP5						1.000	.7845	−.9143	−.9688	−.8859	−.9248
POP513							1.000	−.8900	−.8570	−.6102	−.7561
POP65								1.000	.9665	.8761	.9283
NONWHITE									1.000	.8766	.9195
SCHOOL										1.000	−.9260
EXPEND											1.000

Note: These correlation coefficients are for the natural logarithm of each variable. The variable *EXPEND* is total food expenditure deflated by Stone's Index. Refer to table 1 for definitions of the demographic variables.