Fragility in Dairy Product Demand Analysis

Leigh J. Maynard and Deyu Liu

The authors are, respectively, assistant professor and graduate research assistant, Department of Agricultural Economics, University of Kentucky, 319 Ag. Engineering Bldg., Lexington, KY 40546
email: lmaynard@ca.uky.edu

To be presented at the annual meetings of the American Agricultural Economics Association, Nashville, TN, August 8-11, 1999.

Abstract: Several reasons justify the expectation of increasingly price elastic demand for dairy products. Using weekly scanner data, we find support for this hypotheses, but with wide variation in elasticity estimates across model specifications. The results demonstrate the need for more routine specification testing before basing recommendations on potentially fragile inferences.

keywords: dairy products, demand, scanner data

JEL: D12

Introduction and Background

U.S. dairy product marketers express growing concern that their pricing policies are based on outdated demand elasticities. Reasons to expect more price elastic demand than in previous years include an influx of new substitute products, declining breakfast cereal consumption (Leonhardt, 1998a), changing eating patterns across broad segments of society, demographic changes, and evolving promotion and advertising strategies (Leonhardt, 1998b). Updated dairy product demand analysis can contribute to a range of timely policy issues, including the use of Multiple Component Pricing for Class I milk and the impact of the interstate dairy compacts. The classified pricing system that determines how much dairy handlers pay for milk relies on the assumption that fluid milk is the least elastic of the dairy products: what if that is no longer true? Regional impacts of technological innovations such as Reverse Osmosis can be more accurately forecasted using up-to-date dairy product demand elasticity estimates.

Applied economists are currently being asked to provide recommendations on a wide array of issues that depend on dairy product demand, and the credibility of those recommendations hinges on sound model specification. The ultimate objective of this study is to follow Alston and Chalfant's (1991) advice that we "study fragility in a much more systematic way" to improve the usefulness of applied economics to decision makers in the business and policy arenas.

Elasticity estimates for dairy products over the past 25 years display surprising variation. Each study is unique in its combination of model specification, market level, product aggregation,

study period, time dimension, and selection of exogenous variables. Table 1 shows a sample (admittedly incomplete) of dairy product own-price demand elasticity estimates. Fluid milk estimates range from -0.04 (Huang, 1993) to -2.2 (Green and Park, 1998). Huang estimated a large-scale complete demand system for food using annual U.S. data from 1953 to 1990. In contrast, Green and Park estimated a system of double-log demand equations for weekly store-level sales of milk disaggregated by fat content and brand category. One would expect two such different analyses to produce different findings, but decision makers who request a single, "bottom line" number to use in developing pricing strategy or policy might observe the diversity of estimates and conclude that economic analysis is unable to contribute meaningful information. Not only is it difficult to compare results from such diverse analyses, in many cases time and resource constraints discouraged researchers from performing specification tests to help ensure the robustness of their findings.

Demand Models Estimated

We obtain results from three model specifications to help gauge the robustness of the results. The first model is a quantity-dependent double-log specification. The double-log model is convenient to estimate and interpret, because the parameter estimates themselves represent elasticities. The double-log model lacks a theoretical foundation, however, and does not allow the restrictions implied by classical demand theory to be imposed.

The second model is a linearized AIDS model in levels (Deaton and Muellbauer, 1980), which we refer to as a static LA/AIDS model:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln(m / P) \quad ,$$

where w_i denotes expenditure share of the i^{th} good, p_j denotes price of the j^{th} good, m denotes income, and P denotes the Stone price index such that $\ln P = \sum_j w_j \ln p_j$. The LA/AIDS model is an approximation of the AIDS model that derives from a specific class of preferences that imply a specific functional form of the consumer's expenditure function. The advantages of the LA/AIDS model include its ease of estimation and the ability to conserve degrees of freedom by imposing homogeneity, symmetry, and Engle aggregation restrictions. Disadvantages include inconsistency of estimators when using the Stone price index (Buse, 1994; Alston, Foster, and Green, 1994).

The third model is the general demand system used by Lee, Brown, and Seale (1994) that nests four differential demand systems: Rotterdam, AIDS, CBS, and NBR. *Marginal* budget shares and Slutsky terms are treated as constants in the Rotterdam model, but they are treated as functions of budget share levels in the AIDS model. The CBS model has the AIDS income coefficients and the Rotterdam price coefficients, while the NBR model has Rotterdam income coefficients and AIDS price coefficients. A two-step nonlinear estimation procedure involves first estimating the following model to identify which of the four specifications best describes the data:

$$w_i d \ln q_i = (d_i + \delta_1 w_i) d \ln Q + \sum_j [e_{ij} - \delta_2 w_i (\delta_{ij} - w_j)] d \ln p_j ,$$

where q_i denotes the quantity demanded of the i^{th} good, $dlnQ$ denotes the Divisia volume index, and δ_{ij} denotes the Kronecker delta such that δ_{ij}=1 if i=j, and δ_{ij}=0 if $i \neq j$. The variables d_i and e_{ij} are constructed as follows:

$$d_i = \delta_1 \beta_i + (1 - \delta_1) \theta_i ; \quad e_i = \delta_2 \gamma_{ij} + (1 - \delta_2) \pi_{ij}$$

so that restricting $\delta_1=\delta_2=0$ yields the Rotterdam model, $\delta_1=\delta_2=1$ yields the AIDS model, $\delta_1=1$ and $\delta_2=0$ yields the CBS model, while $\delta_1=0$ and $\delta_2=1$ yields the NBR model. The likelihood ratio test allows one to choose which set of restrictions best describes the data. The second step involves estimating the selected model to obtain elasticity estimates. In this study we imposed the adding-up restriction and did not estimate the "all other goods" equation. We tested for homogeneity and symmetry, and imposed those restrictions when they were not rejected.

Applications using this nested model demonstrate that different demand models are appropriate for different data sets. Lee, Brown, and Seale (1994) applied the nested model to monthly, highly aggregated data over a 20-year period during which Taiwan was developing rapidly. Budget shares for product categories such as education, food, and transportation changed substantially during the study period, and perhaps it is not surprising that the AIDS specification best described the data. Brown, Lee, and Seale (1994) examined juice beverage demand over a four-year period and found that the CBS model best described the data. In this study, which also covered a short period during which little change in budget shares occurred, the NBR model best described the data.

Among the models constructed for this study, conditional demand systems and varying coefficient models were explored but not fully developed after initial results appeared to offer no new insights. Numerous specification tests can and should be performed before the analysis is complete. Tests for structural change are another consideration, but may be of limited utility given the study period of only two years. Perhaps most importantly, the issue of scaling in prices (Buse, 1994; Moschini, 1995) was not addressed in obtaining the results presented in this paper, but will be considered imminently.

Data

The analysis relies on weekly national average retail scanner data provided by A.C. Nielsen via the International Dairy Foods Association for the period November 1996 through October 1998. Price and quantity data exist for white and flavored milk, six categories of cheese, four categories of table spreads, five categories of frozen desserts, carbonated beverages, and orange juice. Product form rather than product type defines the cheese categories: chunk/loaf, sliced, shredded, snack/spread, cubed, and grated. Frozen dessert categories are ice cream, frozen yogurt, sorbet, sherbet, and frozen novelties. Table spread products are butter, margarine, spreads, and blends.

The availability of scanner data is a great boon to applied economists, but it does have limitations. The data used in this study come from retail grocery stores with over $2 million in annual sales. Dairy products sold through superstores, convenience stores, and the hotel, restaurant, and institutional sector are not recognized in this data. National aggregation of the data also dilutes the influence of promotional activities and regional impacts such as weather events. Along the temporal spectrum, weekly scanner data is less aggregated than data available through most other sources. Although short-run elasticities are expected to be smaller (in absolute value) than long-run elasticities, weekly data may recognize stockpiling behavior not recognized by monthly or quarterly data.

In addition to prices and quantities, data include monthly media advertising expenditures for several beverage categories, monthly personal consumer expenditures, and variables reflecting seasonality, holidays, and time trends. Personal consumer expenditure data were gathered from the Bureau of Economic Analysis. Preliminary analysis demonstrated that the stock variable we constructed from the media advertising expenditures was not useful in explaining national-level

demand behavior, and the advertising variables were dropped from subsequent analysis. Seasonality was represented by a cosine transformation such that the variable equaled one in the summer and negative one in the winter. A holiday dummy variable equaled one during weeks immediately before and during seven major holidays (New Year's, Easter, Memorial Day, July 4th, Labor Day, Thanksgiving, Christmas).

Results

The results of the first stage estimation of the nested differential demand model suggested that the NBR model best described the data. The estimated value of the parameter δ_1 was 0.03 with a standard error of 0.002 (significantly different from δ_1=0, but δ_1=1 would certainly be unreasonable), while the estimated value of the parameter δ_2 was 0.94 with a standard error of 0.31 (not significantly different from δ_2=1).

Own-price elasticity estimates from three representative demand models (differential NBR, static LA/AIDS, and static double-log) are shown in Table 2. Bearing in mind that the nested model alone estimates over 150 parameters, complete results are not shown in this paper, but are available from the authors upon request. In general, cross-price terms were not statistically significant across product categories (e.g., white milk vs. ice cream), but cross-price terms were often significant within a product category (e.g., chunk cheese vs. shredded cheese). Income terms in the NBR and double-log models were only occasionally significant, and even in those cases the estimates implied income elasticities nearly equal to zero. In contrast, income terms were generally not significant in the static LA/AIDS model, implying income elasticities equal to one. Seasonality and holiday parameter estimates in all models were typically significant and of the expected sign. In the static LA/AIDS and static double-log models, time trend parameters

were significant and positive for flavored milk (as expected), snack cheese, and butter, while frozen yogurt showed a significant negative time trend.

The own-price elasticities shown in Table 2 are of primary interest to public and private sector decision makers and researchers interested in the robustness of econometric results. The results appear to confirm the suspicions of industry marketers that most dairy products are more price elastic than most previous studies indicate, implying a need for equally responsive pricing systems and strategies. As Bailey and Gamboa (1999) note, however, elasticities generated from weekly scanner data are historically higher in absolute value than elasticities generated from disappearance data that are more highly aggregated across both products and time. A noteworthy finding is that fluid milk still appears to be the least elastic of the dairy products, consistent with the premise underlying the classified pricing system used in the United States.

Many of the elasticities estimated from all three of the models appear unreasonably elastic, particularly those of the four product forms of cheese. One must question the extent to which elasticities can be compared across studies when the data characteristics differ so widely, and this question cannot be answered without comparative analysis based on various aggregations of a single data set.

The purpose of estimating three different types of demand models was to assess the robustness of the results, which appear highly product specific. Flavored milk own-price elasticity estimates all fell within a narrow range from -1.40 to -1.47. The ranges of own-price elasticity estimates for white milk, sliced cheese, frozen yogurt, and frozen novelty own-price elasticities were much larger but relatively modest compared to the ranges observed for chunk cheese, shredded cheese, snack cheese, ice cream, and especially butter. In all but two cases, the differential NBR model produced the most elastic estimates. Further work is needed to establish

why the three models yield similar estimates in some cases and dramatically different estimates in other cases.

Conclusions

The goals of this analysis were to investigate expectations of increasingly elastic dairy product demand, and to determine if the results were sensitive to the type of demand model estimated. One comes away from the analysis with two main impressions: (1) evidence of more elastic demand is tempered by concern that scanner data produces results not comparable to those produced by the data sources used in many previous studies, and (2) the wide variation in elasticity estimates across models demonstrates a need for thorough specification testing that goes beyond academic considerations. Without (forthcoming) further analysis, no basis exists for choosing one of the models as the basis for pricing or policy recommendations.

Ongoing research designed to provide stakeholders with reliable elasticity estimates and to investigate the empirical characteristics of various demand modeling techniques includes system misspecification testing (e.g., McGuirk et al., 1995) and Monte Carlo simulation to explore factors influencing the robustness of elasticity estimates.

References

Alston, J.M. and J.A. Chalfant. "Can We Take the Con Out of Meat Demand Studies?" *Western J. Agr. Econ*. 16,1(1991):36-48.

Alston, J.M., K.A. Foster, and R.D. Green. "Estimating Elasticities with the Linear Approximate Almost Ideal Demand System: Some Monte Carlo Results." *Rev. Econ. and Stat*. 76(May 1994): 351-356.

Bailey, K. and J. Gamboa. "A Regional Economic Analysis of Dairy Compacts: Implications for Missouri Dairy Producers." Report posted at http://agebb.missouri.edu/commag/bailey/dairy/compact/ , Commercial Agriculture Program, University of Missouri, 1999.

Blisard, N., D. Blayney, R. Chandran, D. Smallwood, and J. Blaylock. "Evaluation of Milk and Cheese Advertising, 1984-96." Technical Bulletin no. 1860, USDA, Economic Research Service, December 1997.

Boehm, W.T. "The Household Demand for Major Dairy Products in the Southern Region." *Southern J. Agr. Econ*. 7(1975):187-196.

Brown, M.G., J.-Y. Lee, and J.L. Seale, Jr. "Demand Relationships Among Juice Beverages: A Differential Demand System Approach." *J. Agr. and Applied Econ*. 26(1994):417-429.

Buse, A. "Evaluating the Linearized Almost Ideal Demand System." *Amer. J. Agr. Econ*. 76(1994):781-793.

Deaton, A. and J. Muellbauer. "An Almost Ideal Demand System." *Amer. Econ. Rev*. 70(1980): 312-326.

Gould, B.W. "Factors Affecting U.S. Demand for Reduced-Fat Milk." Staff Paper no. 386, University of Wisconsin-Madison, Agricultural Economics, October 1995.

Green, G.M. and J.L. Park. "Retail Demand for Whole vs. Low-Fat Milk: New Perspectives on Loss Leader Pricing." Prepared for the annual meetings of the AAEA, Salt Lake City, Utah, August 2-5, 1998.

Hall, J. "Everyday Pricing Analysis, Milk Category." ACNielsen Advanced Analytics, Report prepared for Dairy Management, Inc., December 1997.

Heien, D. and C.R. Wessells. "The Demand for Dairy Products: Structure, Prediction, and Decomposition." *Amer. J. Agr. Econ*. 70(1988):219-228.

Huang, K.S. "A Complete System of U.S. Demand for Food." Technical Bulletin no. 1821, USDA, Economic Research Service, September 1993.

Lee, J-Y, M.G. Brown, and J.L. Seale, Jr. "Model Choice in Consumer Analysis: Taiwan, 1970-89." *Amer. J. Agr. Econ*. 76(1994):504-512.

Leonhardt, D. "Cereal Box Killers Are On the Loose." *Business Week*, (October 12, 1998):74-77.

Leonhardt, D. "Got Milked?." *Business Week*, (November 9, 1998):52.

Liu, D.J. and O.D. Forker. "Generic Fluid Milk Advertising, Demand Expansion, and Supply Response: The Case of New York City." *Amer. J. Agr. Econ*. 70(1988):229-236.

Maynard, L.J. "Empirical Tests of the Argument that Consumers Value Stable Retail Milk Prices." Staff Paper no. 380, University of Kentucky, Agricultural Economics, October 1998.

McGuirk, A., P. Driscoll, J. Alwang, and H. Huang. "System Misspecification Testing and Structural Change in the Demand for Meats." *J. Agr. Res. Econ.* 20,1(1995):1-21.

Moschini, G. "Units of Measurement and the Stone Index in Demand System Estimation." *Amer. J. Agr. Econ*. 77(1995):63-68.

Xiao, H., H.W. Kinnucan, and H.M. Kaiser. "Advertising, Structural Change, and U.S. Non-Alcoholic Drink Demand." Research Paper no. 98-01, National Institute for Commodity Promotion Research and Evaluation, March 1998.

Table 1. Dairy Product Demand Elasticity Estimates Depend on Data and Methods

	Fluid milk	Cheese	Butter	Ice Cream
Boehm (1975)	-0.14	-2.17	-0.73	-0.69
Heien & Wessels (1988)	-0.63	-0.52	-0.73	
Liu & Forker (1988)	-0.29			
Huang (1993)	-0.04	-0.25	-0.24	-0.08
Gould (1995)	-0.60			
Hall (1997)	-0.32 to -0.76			
Blisard et al. (1997)	-0.07	-0.56 to -0.84		
Maynard (1998)	-0.58 to -0.76			
Xiao et al. (1998)	-0.16			
Green & Park (1998)	-0.89 to -2.20			
Bailey & Gamboa (1999) *	-0.32	-0.35	-0.50	

* Bailey and Gamboa assumed these elasticities for use in a simulation model; they are shown here to provide a representative example of elasticities considered by many experts to be reasonable

Table 2. Own-price Demand Elasticity Estimates Often Differ Widely Across Models

	NBR (differential)	Static LA/AIDS	Double-Log
White milk	-0.78	-0.63	-0.54
Flavored milk	-1.47	-1.40	-1.41
Chunk/loaf cheese	-3.03	-1.96	-2.18
Sliced cheese	-2.08	-1.72	-1.64
Snack cheese	-0.99	-1.68	-0.58
Shredded cheese	-2.66	-1.70	-1.35
Butter	-2.33	-0.19	-0.63
Ice cream	-1.65	-0.65	-0.88
Frozen yogurt	-1.64	-1.49	-1.31
Frozen novelties	-3.18	-3.39	-2.99