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Households' Choices Among Fluid Milk Products: What Happens When Income and Prices Change?

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Households' Choices Among Fluid Milk Products: What Happens When Income and Prices Change?

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Abstract

Households have several ways to economize on their purchases at retail food stores when prices increase or their incomes fall. This report investigates a household's choice among retail fluid milk products categorized along three dimensions: three levels of fat content, two levels of package size, and organic versus conventional methods of production. Nielsen Homescan data from 2007-08 are used to estimate a choice model, which accounts for price, income, and other choice determinants. Results show that small changes in prices and income have a modest impact on a household's choice among milk products. However, households mitigate the impact of more substantial price and income shocks by switching from more expensive to less expensive products. We also find that the demand for organic milk is more sensitive to swings in income and food prices than is demand for conventional milk.

Keywords: milk purchases, milk prices, dairy product, dairy prices, organic milk, household income, household food economizing behavior, Homescan data, fluid milk, recession

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Summary

What Is the Issue?

Many households experienced a decrease in income during the 2007-2009 recession. At the same time, food prices rose. In 2008, the median U.S. household made 3.6 percent less money after adjustment for inflation than it did in 2007, while prices for fluid milk at retail food stores rose 11.6 percent in 2007 and 6 percent in 2008. Households have several ways to economize on their retail food purchases when prices increase or their incomes fall. More information on how households economize on their purchases may help policymakers better understand the relationship of consumer choices to changes in the economy and to a host of demographic variables.

What Did the Study Find?

Households experiencing an income decrease may look for ways to stretch their food dollar, such as seeking out promotions or shopping at less expensive stores like supercenters. This study focuses on the type of fluid milk a household buys. Fluid milk that is higher fat, organic, or packaged in small containers is more expensive per gallon than milk that is lower fat, conventionally produced, or packaged in large containers. Households typically switch to less expensive products when their incomes decrease. For instance, households save money by choosing fluid milk products with a lower fat content or by switching from organic to conventional milk.

Households with an increase in income, however, do not always buy more expensive products:

A 10-percent increase in household income:

- Raises the probability of purchasing organic milk from 3 to 3.7 percent;
- Raises the probability of buying low-fat milk (defined as "skim and less than 2 percent fat") from 47 to 48.6 percent;
- Lowers the probability of purchasing whole milk (at least 3.25 percent fat) from 17 to 15.9 percent;
- Lowers the probability of choosing reduced-fat milk (between 2 and 3.25 percent fat) from 36 to 35.5 percent; and
- Has only a small effect on households' choice among products in different container sizes.

Changes in retail prices also affect a household's choice among different milk products:

- A small (1-percent) increase in prices for all milk products has only a small effect on the division of sales among products with different levels of fat content and in different package sizes, as well as division of sales between milk produced using conventional and organic methods.

- A large ($1 per gallon or approximately 25-percent) increase in retail milk prices is large enough to curb growth in sales of organic milk.
- A large increase in prices for all milk products also increases the probability—from 47 to 53.9 percent—of purchasing low-fat milk.
- Even large price shocks have little effect on households' choice between package sizes. The probability of purchasing milk in a container smaller than 1 gallon decreases from 42 to 40.2 percent.

Overall, when substantial price and income shocks occur, households switch from more expensive to less expensive products. This practice may help households afford a healthful diet when budgets get tight. However, many lower income Americans already (before income reductions or general price increases) purchase less expensive items; likewise, lower income households are less likely to choose organic milk. This lack of flexibility may render households already on a tight budget more exposed to the effects of price volatility.

In general, demand for organic milk is more sensitive than demand for conventional milk to swings in income and food prices. Past research suggests that many buyers of organic milk question conventional production methods and believe organic products to be safer and/or more healthful. Nonetheless, during the recent recession, when incomes declined and prices rose, growth in organic milk sales stalled.

How Was the Study Conducted?

We investigate a household's choice among retail fluid milk products categorized along three dimensions: three levels of fat content, two levels of package size, and organic versus conventional methods of production. Categorizing retail products along all 3 dimensions yields 12 specific products (e.g., low-fat organic milk in a 1-gallon container). A unique multinomial logit choice model is applied to account for past household purchase behavior, price, promotional deal, and seasonality. It also accounts for household demographic variables such as income and number of household members, as well as the age, employment status, education, and ethnicity of the head of household and whether or not the home was owned. We use 2007-2008 Nielsen Homescan data to estimate the choice model. Finally, using model results for each of the 12 specific products, we simulate how shocks to prices, income, and other demand determinants would affect the probability that a household buys lower fat versus higher fat fluid milk, conventional or organic products, and fluid milk packaged in a 1-gallon or smaller container.

Introduction

Households may need to stretch their food dollars either when their incomes decrease or when food prices increase. Many Americans experienced both of these conditions during the December 2007 to June 2009 recession. This report examines the question of how consumers adjust their choices when faced with income and price shocks for a staple (in this report, fluid milk), which is available in a variety of retail forms and container sizes.

Households have several ways to economize on their purchases at retail food stores when prices increase or their incomes fall. They may buy smaller quantities of some foods, but ultimately, they need to eat. Aside from buying less food, Leibtag and Kaufman (2003), for example, show that households may adjust their purchase behavior by shopping at less expensive stores or substituting less expensive foods. This project focuses on the second possibility: we investigate households' choices among fluid milk products (1) sold in gallon versus less-than-gallon containers, (2) produced using organic versus conventional methods, and (3) containing more and less milk fat. That is, when prices and income change along with other variables, how do households adjust their choices among these substitute fluid milk products?

The median U.S. household saw its income fall 3.6 percent in 2008 and 0.7 percent in 2009 after adjustment for inflation.[1] In addition, food prices had already begun to rise in early 2007. Food price inflation reached 4 percent in 2007 and 5.5 percent in 2008 before moderating to 1.8 percent in 2009.[2] Foods that became substantially more expensive included staples like fluid milk. Prices for milk at retail food stores rose 11.6 percent in 2007 and 6 percent in 2008 before ultimately falling 13.2 percent in 2009.[3]

The price of 2 percent milk rose above $4 per gallon in many U.S. cities during the 2007-08 peak of inflation.[4] Kumcu and Kaufman (2011) show that, in general, consumers reacted to the combination of lower incomes and higher food prices over these years by economizing on their food purchases. They took advantage of sales, promotions, and coupons; substituted comparable, but lower cost foods; and sought stores with lower prices and more cost-effective selections.

Fluid milk is a staple of the American diet, and it is especially important to young people. Americans consumed about 0.75 cup per day, on average, in 2005-06 (Sebastian et al., 2010), and during those same years, children ages 2 to 11 consumed between 1.25 and 1.5 cups per day. Cornick et al. (1994) found that 96.1 percent of all households bought fluid milk over a 1-year period in the early 1990s.

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[1] Based on data provided by the U.S. Census Bureau. See DeNavas-Walt et al. (2011).

[2] Based on the Consumer Price Index (U.S. city average) as reported by the Bureau of Labor Statistics (2012).

[3] Based on the Consumer Price Index (U.S. city average) as reported by the Bureau of Labor Statistics (2012).

[4] Through its administration of Federal milk marketing orders, the USDA Agricultural Marketing Service (AMS) generates data on milk supplies, utilization, sales, plant prices, over-order payments, and retail prices for packaged milk. See USDA/AMS (2012).

Furthermore, the *Dietary Guidelines for Americans, 2010* encourages consumption of dairy products.[5] Americans are advised that consuming enough dairy products can improve bone health and lower blood pressure, as well as reduce the risk of cardiovascular disease and type 2 diabetes. However, "most" Americans aged 4 and over consume less than the recommended quantity of dairy products (p. 38).

Although milk has long been considered a major food product to provide necessary nutrients such as calcium, milk fat has also been viewed as a contributor to obesity in America. Fat-free and low-fat fluid milk provide necessary nutrients, such as calcium, with fewer calories than higher fat dairy products. Thus, the type of milk a household buys plays a role in its members' health. Whether or not consumers substitute between whole milk and lower fat products will affect not only their budgets, but also how closely they adhere to Federal dietary guidelines.

In addition to affecting health, consumer choices of milk products influence dairy production trends. One example of such influence is in organic dairy production. Organic dairy farmers represent a small but growing share of the overall market for fluid milk. To qualify for certification under USDA's National Organic Program, conventional milk producers must undergo a process that can be challenging and costly (McBride and Greene, 2009). To help cover those costs and support the recent growth in organic dairy farming, farmers have largely relied on the willingness of many consumers to pay a premium for organic milk. Smith et al. (2009), for example, find that the organic premium for a half-gallon of low-fat milk is between 72 and 88 percent, depending on whether the milk is also branded. Because of the financial risk involved, conventional milk producers thinking of switching to organic production need information not only on consumers' willingness to pay, but on the robustness of that willingness, in the face of price and income shocks.

In this report, we investigate a household's choice among retail fluid milk products categorized along three dimensions: three levels of fat content,[6] two levels of package size ("1 gallon" and "less-than-gallon sized"), and organic versus conventional methods of production. Categorizing retail products along all 3 dimensions (e.g., low-fat organic milk in a 1-gallon container) yields 12 specific products. We estimate a choice model that allows predicting the effects of changes in prices and income, among other factors, on a household's choices among the 12 products. Results obtained in this study may help policymakers better understand the relationship of consumer choices to changes in the economy and to a host of demographic variables.

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[5] The *Dietary Guidelines for Americans* is issued by the USDA and the U.S. Department of Health and Human Services to provide evidence-based nutrition information and advice for people age 2 and older. It also serves as the basis for Federal food and nutrition education programs.

[6] *Low-fat* milk is defined as less than 2 percent fat including skim; *reduced-fat* is between 2 and 3.25 percent fat; and *whole* is at least 3.25 percent fat.

Households' Purchases of Fluid Milk

When prices rise or incomes fall, consumers tend to reduce the quantity of milk that they consume by a proportionally smaller amount. A review of existing research by Andreyeva et al. (2010) identifies 26 studies that estimate the price elasticity of demand for milk using either time series or cross-sectional data. The average reported estimate was -0.59, meaning that if the price of milk were to increase (or decrease) by 10 percent, the expected decrease (or increase) in the quantity consumed would be only 6 percent. However, during the past recession, despite the rise of milk prices and fall of incomes, quantities of milk consumed were unusually stable. Loss-adjusted food availability data reveal that per capita consumption remained about 14.5 gallons per person per year (USDA-ERS, 2012).

In a recession or when prices increase, households may seek to economize in ways other than consuming less of staple foods. One way is shopping at less expensive stores. Dong and Stewart (2012) show that, after an income decrease, a household is more likely to buy fluid milk at a supercenter than at either a traditional grocery store or club warehouse. Another way that households may economize is by substituting less expensive products for more expensive ones.

For the analysis, we use 2007 and 2008 Nielsen Homescan data to investigate a household's choices among retail milk products. Nielsen maintains a consumer panel that demographically and geographically represents the continental United States. Participating households from all 48 contiguous States are given scanners to keep in their homes. After a shopping occasion, panelists use these scanners to record food purchases, including the Universal Product Code (UPC), the quantities bought, the amount of money paid, the purchase date, and price promotions, if any. The data are likewise daily transaction data and include purchases at all grocery retail stores. Homescan panelists do not record purchases at foodservice outlets including restaurants and, most importantly, in the case of fluid milk, schools.

It is possible that some households make mistakes when reporting information to Nielsen (e.g., some may fail to report all purchases because the recording process is time consuming). However, Einav et al. (2008) analyze the accuracy of these data and find that errors in Homescan data are of the same order of magnitude as reporting errors in Government-collected data sets commonly used to measure earnings and employment status.

The Homescan data used in this study include information on purchases by 24,110 households. For each of these, Nielsen provides detailed information on each transaction as well as information on each household's demographic characteristics and county of residence.

The data confirm that most American households buy fluid milk. Although prices rose in 2007, the Homescan data show that 95.2 percent of households still bought fluid milk that year, about 0.9 percent less than reported by Cornick et al. (1994). In 2008, 94.8 percent of households bought fluid milk.

Retail food stores typically offer a wide array of fluid milk products. We divide this array along three dimensions (table 1). The first of these dimensions is fat content, with levels defined as *whole* (at least 3.25 percent fat), *reduced-fat* (between 2 and

Table 1
Fluid milk products and marketing variables

Fluid milk product descriptions (by fat content, container size, and means of production)	Average daily price	Average daily share of sales made on a deal	Purchase frequency annual and seasonal				
			Annual	Winter	Spring	Summer	Fall
	Dollars per gallon	*Percent*	*Percent*				
1. Whole, 1 gallon, conventional	3.57	14.6	8.8	8.8	8.9	8.7	9.1
2. Reduced-fat, 1 gallon, conventional	3.38	17.5	20.8	20.7	20.6	20.7	21.1
3. Low-fat, 1 gallon, conventional	3.27	19.7	27.5	27.5	27.5	27.6	27.4
4. Whole, less than gallon, conventional	5.30	9.9	7.8	8.0	7.6	7.8	7.9
5. Reduced-fat, less than gallon, conventional	5.04	13.3	14.0	13.9	14.0	14.1	13.8
6. Low-fat, less than gallon, conventional	4.93	15.3	18.1	18.1	18.4	18.1	17.6
7. Whole, 1 gallon, organic	5.60	20.2	0.1	0.1	0.1	0.1	0.1
8. Reduced-fat, big 1 gallon, organic	5.24	11.7	0.1	0.1	0.1	0.1	0.2
9. Low-fat, 1 gallon, organic	5.21	18.8	0.3	0.3	0.3	0.3	0.4
10. Whole, less than gallon, organic	7.28	19.0	0.5	0.5	0.5	0.5	0.4
11. Reduced-fat, less than gallon, organic	7.19	17.7	0.7	0.7	0.7	0.7	0.7
12. Low-fat, less than gallon, organic	7.15	21.3	1.3	1.4	1.3	1.4	1.2

Note: Average daily prices for each of the 12 products are the average prices over all the dates of the year. Other values in the table are proportions. Gallon-sized containers of conventional low-fat or skim milk accounted for 27.5 percent of all purchases annually and were the most often purchased product.

Low-fat milk is defined as less than 2 percent fat including skim; *reduced-fat* is between 2 and 3.25 percent fat; and *whole* is at least 3.25 percent fat.

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

3.25 percent milk fat), and *low fat* (less than 2 percent milk fat). Other product dimensions include package size (i.e., gallon or in smaller sized packages), and, finally, whether milk is produced by conventional or organic methods.

Dividing retail milk products along all 3 dimensions produces 12 distinct milk products. For example, conventionally produced, low-fat milk in a gallon container is the most frequently bought product (28 percent of all purchases), while organic whole and organic reduced-fat milk sold in gallon containers tie for least frequently bought (both with less than 0.1 percent of total sales). The prices used in this report are average daily prices paid by households for each of the 12 different milk products.[7] Over 2007-08, the least expensive product was conventional low-fat milk sold by the gallon for $3.27 (table 1). The most expensive was organic whole milk sold in a less-than-gallon container at $7.28 per gallon.

[7] For each given date, the prices for each of the 12 products are the average prices across households that purchased the products on that date. If no households purchased any of the 12 products on that particular date, we instead use that week's average prices.

Products may have also been purchased while being promoted by either a manufacturer or a store. Promotional deals include manufacturer coupons, store coupons, and store features, among others. The promotional deal variable is the share of each day's purchases of each product that were made on promotion.

What are the most purchased types of milk products? When the 2007-2008 retail market is sorted according to products' fat content, low-fat and skim milk accounted for 47 percent of all purchases by U.S households; reduced-fat milk accounted for 36 percent; and whole milk accounted for 17 percent of all purchases. Regarding container size and organic purchases, the research shows that households bought milk in a gallon-sized container 58 percent of the time, and all six organic products collectively accounted for about 3 percent of all purchases.

Casual observation reveals that food retailers often sell whole, reduced-fat, and low-fat milk for the same price, but, on average, they sell higher fat products at a higher price. Consider prices paid for conventional milk packaged in a less-than-gallon container. Consumers paid $4.93 per gallon for low-fat milk versus $5.30 for similarly packaged, conventionally produced, whole milk (table 1)—a premium of $0.37 per gallon. Under Federal milk marketing orders, the minimum price paid to farmers for fluid milk is higher for higher fat products. Fat extracted from fluid milk is valuable because it is used to make other dairy products like cream and butter.

Cornick et al. (1994) and, more recently, Davis et al. (2010) examine the effects of a household's income and demographic characteristics on its purchases of whole and lower fat milk products. Davis et al. (2010) find that Black households and households with young children purchase more whole milk than other households. By contrast, high-income households and households whose female head of household has attended college tend to buy more lower fat products.

Another of this report's product dimensions considers the variety of fluid-milk package sizes, the most common being the gallon container. Buying milk this way costs less per gallon. Consumers paid $3.27 for conventional low-fat milk in a gallon container versus $4.93 per gallon for this same type of milk in smaller containers—a premium of $1.66 per gallon (table 1). Though it stands to reason that lower income households might economize by purchasing products in larger containers, Leibtag and Kaufman (2003) find that lower income households are less likely to take advantage of economy-sized packages for ready-to-eat cereal, meat, poultry, fruits, vegetables, and cheese, among other products. One possible explanation is that households living on a tight budget cannot afford to "stock up" on staples. Another is that lower income households have less storage space in their homes. The data used by Leibtag and Kaufman (2003) did not include fluid milk.

The study's third product dimension tracks whether fluid milk purchases were produced using organic or conventional methods. McBride and Greene (2009) note that conventional dairy farmers switching to organic production must make changes in animal husbandry, alter land and crop management, and secure organic feed, among other endeavors. The process can be challenging and costly. Sales of organic milk have, nonetheless, grown rapidly since the 1990s.

Chronicling this growth, Dupuis (2000) notes that many buyers of organic milk question conventional production methods and believe organic products to be safer and/or more healthful. The use of the hormone Recombinant Bovine Somatotropin (rBST) to increase production yields was once particularly controversial. Several studies have since measured the premium that some consumers are willing to pay for organic milk. As noted above, Smith et al. (2009) demonstrate that this premium can be substantial. Kiesel and Villas-Boas (2007) find that the USDA organic seal increases the probability of purchasing organic milk.

Despite these findings, growth in organic milk sales stalled during the recent recession. Organic products accounted for 2.7 percent of all U.S.-marketed fluid milk in December 2007 at the onset of the recession.[8] That share was nearly unchanged at 2.8 percent in December 2009, about 6 months after the recession had ended. Growth did eventually recover along with the economy. Organic products accounted for 3.9 percent of all milk marketed in the United States in December 2011.

When prices rise or incomes fall, do buyers of organic milk switch back to conventional products? And what determines which consumers choose to buy organic milk and which continue to choose conventional products? Dhar and Foltz (2005) estimate a demand model for organic milk products, conventional milk labeled as rBST-free, and unlabeled conventional milk. They find that the demand for organic products is more price sensitive than the demand for unlabeled conventional products. Also, they confirm that unlabeled conventional milk is a substitute for organic milk. A later study by Alviola and Capps (2010) finds that the demand for organic milk is also relatively more sensitive to changes in income. Moreover, the demand for organic milk varies with a person's level of education, race, ethnicity, and household size, among other things. College-educated households in particular are more likely to exhibit a preference for organic milk over conventional products.

Milk Purchase Choice Model

Our review of existing research on the demand for milk by American households reveals that households make purchase choices based partly on the attributes of the available products and partly on prices and the use of promotional deals. For example, Dhar and Foltz (2005) find that the demand for organic products is price sensitive, although other studies like Smith et al. (2009) also show that some households are willing to pay a significant premium. These households may feel that organic products are safer and/or more healthful.

Also important are a household's own characteristics, which can cause it to exhibit a preference for a particular type of milk product. These characteristics include not only income and demographics, as discussed above, but also past purchase history. Guadagni and Little (1983) demonstrate that habit formation can significantly affect food choices. Specifically, in a study of a household's choice among various ground coffee products, Guadagni and Little (1983) demonstrate that a household may choose a particular type of product and thereafter exhibit a tendency to choose that same product in the future. Among the demographic characteristics of households, it has been demonstrated that income, level of educational attainment, household size,

[8] See USDA Agricultural Marketing Service (AMS) (2012).

race, and ethnicity, among other factors, can influence the type of milk a household consumes (e.g., Davis et al., 2010).

We now estimate a choice model that accounts for the major determinants of a household's choice among fluid milk products. The multinomial logit model has been widely used to study a household's choice among food products in general. However, the standard form of this model does not account for all of the key choice determinants. To obtain a satisfactory model, we instead start by defining a consumer's utility over the 12 milk products analyzed in this report. For household *i*, the utility to buy food product *j* at time *t* is defined as follows:

(1) $$U_{ijt} = \alpha_j + \beta X_{jt} + L_{ijt}(\theta; Y_{ijt-1}, Z_i) + \varepsilon_{ijt} ,$$

where α_j is an intercept that captures the contribution to consumer utility of the attributes associated with food product *j*. X_{jt} is a vector of marketing variables, such as prices and any promotional deals for product *j* at time *t*. X_{jt} may also account for the season of the year. β and θ are vectors of parameters to be estimated. L_{ijt} is a household characteristic variable whose value is determined by the household's demographic characteristics (Z_i) and past purchasing history Y_{ijt-1} prior to time t. Y_{ijt-1} can be defined as a (t-1) x 1 vector of 0's and 1's with the *r*th element equal to 1 if household *i* purchased product *j* at time *r* and equal to zero otherwise. In research on choice models, L_{ijt} is commonly called the "loyalty variable," because it accounts for a household's past purchase history, among other things. Finally, as in Guadagni and Little (1983), we assume that household utility further contains a random component, ε_{ijt}.

Alternative approaches for modeling a household's choice among competing food products include the random coefficient logit model. This model allows for household heterogeneity by assuming that β is randomly distributed across households. However, the estimation of a random coefficient model usually requires the evaluation of high order probability integrals. Therefore, the model in (1) is relatively much easier to estimate. Also, we can use L_{ijt} to differentiate utility U_{ijt} among households. We can, therefore, explicitly model the effects of household demographic variables and a household's past purchase history, as discussed further below—something not possible using a traditional random coefficient logit model.

The specification of the loyalty variable, L_{ijt}, to incorporate household characteristics into choice models is a subject of much research. Guadagni and Little (1983) propose a specification that uses a weighted average of past choice behavior. Recent choices are weighted more heavily. Fader and Lattin (1993) propose an alternative specification in which habits can change with sudden, unforeseen events. For example, a promotional campaign may cause a consumer to try a new product. However, both studies ignore household demographics. Dong and Stewart (2012) expand on Fader and Lattin's (1993) approach by additionally including household demographics in L_{ijt}. In this study, we follow Dong and Stewart (2012) to account for both household demographics and past purchase behavior in specifying variable L_{ijt} (See appendix I.)

A household chooses among products to maximize utility. The probability that household *i* selects product *j* at time *t* is therefore p_{ijt} = Prob ($U_{ijt} > U_{ikt}$) for all *k* not equal to *j*. If we further assume the random component in utility, ε_{ijt}, is an independently distributed random variable with a type II extreme value (double exponential) distribution, the value of p_{ijt} is

$$(2) \qquad p_{ijt} = \frac{e^{U_{ijt}}}{\sum_{l=1}^{J} e^{U_{ilt}}},$$

which serves as the basis of our multinomial logit choice model.

An assumption of the multinomial logit model is that the odds ratios, p_j/p_k, based on equation (2) are independent of the other alternatives. This assumption is the so-called "Independence from Irrelevant Alternatives" (IIA), and it stipulates that the choice alternatives in the model are mutually independent. If this assumption is violated, systematic errors will occur in the predicted choice probabilities (Guadagni and Little 1983). We use the Hausman-McFadden approach (Hausman and McFadden, 1984) to test the validity of this assumption for the empirical model.

Another assumption of the model is that households choose only one type of milk at a time. For example, if household *i* bought two types milk at time *t*, we would treat these purchases as two separate purchase occasions on which one type of milk was bought. Dube (2004) developed a model that can handle multiple purchase units using a Poisson model to predict the number of consumption occasions across all household members. However, similar to the random coefficient logit model, Dube's (2004) model also requires evaluating high order probability integrals. In our data, only 5.25 percent of all purchases were made on the same day as another type of milk was bought.

The log likelihood function for this multinomial logit choice model, given a purchase history (y_{ijt}), can be written as

$$(3) \qquad \ln L = \sum_{i=1}^{N} \sum_{j=1}^{J} \sum_{t=1}^{T} y_{ijt} \ln p_{ijt}$$

where *N* is the total number of households, *T* is the total number of purchase occasions, and *J* is the total number of alternative products to be chosen. Model estimates can be obtained from maximizing equation (3).

The marginal effect of *X*, the seasonality and marketing variables, on the product choice probabilities can be derived from equation (2) for household *i* as

$$(4) \qquad \frac{\partial P_{ij}}{\partial X_l} = \begin{cases} P_{ij}(1-P_{ij})\beta, & if\ l = j \\ -P_{ij}P_{il}\beta, & if\ l \neq j \end{cases}$$

where P_{ij} is the average probability of household *i* purchasing product *j* over all the purchase occasions. The associated elasticity can be written as:

$\frac{\partial P_{ij}}{\partial X_l}\frac{X_l}{P_{ij}} = X_l(1-P_{ij})\cdot\beta$ for $l = j$ and $\frac{\partial P_{ij}}{\partial X_l}\frac{X_l}{P_{ij}} = -X_l P_{ij}\cdot\beta$ for $l \neq j$, where X_l is the vector of average seasonality and marketing variables associated with product *l* over all the purchase occasions.

The household variables Z_i are incorporated into the household loyalty variable L_{ijt}. The elasticity of product choice probability with respect to Z_i can be derived from equation (2) as

$$(5) \qquad \eta_{jZ} = \frac{\partial P_{ij}}{\partial Z_i}\frac{Z_i}{P_{ij}} = (\frac{1}{L_{ij}}\frac{\partial L_{ij}}{\partial Z_i} - \sum_{l=1}^{J} P_{il}\frac{1}{L_{il}}\frac{\partial L_{il}}{\partial Z_i})\cdot Z_i$$

where all the variables are the average values over all the purchase occasions by household *i*.

We use the Homescan data described above to create all the variables needed in both *X* and *Z*. The marketing variables (*X*) used in this study include milk price, promotional deal, and seasonal dummies (table 1). Based on previous milk purchase studies, we include the following among demographic variables: household income, household size, age, employment, education level of the female household head, and household ethnicity in *Z*. The presence of small children and teenagers usually influences household milk consumption, so we further include binary variables to indicate if households have small children (younger than 6) and young teenagers (between 13 and 17). We also include a dummy variable to indicate single-person households, because single people may behave differently from other types of households regarding food purchases. To capture variation in milk demand across households living in rural/suburban communities and inner-city neighborhoods, we include a population density variable (the population per square mile in a household's county of residence). Summary statistics for the demographic variables are provided in table 2.

Many Underlying Factors to Households' Product Choices

The multinomial logit model in equation (2) was estimated using the data on 24,110 Homescan households over 730 days (the 2 years of 2007 and 2008). Each household could have bought milk on each of these days. Households made an average of 58 purchases during the 2 years. The total number of milk purchases (observations) in the data is 1,390,263. The log likelihood in equation (3) was maximized using GAUSS software. The standard errors of the estimated parameters were then obtained from the inverse of the numerically evaluated Hessian matrix of the likelihood function (parameter estimates, standard errors, and the value of the log likelihood function evaluated at these parameter estimates are reported in the appendix II).

As mentioned above, the multinomial logit choice model assumes IIA. To test this assumption, we follow Hausman and McFadden (1984). We re-ran the model including only the six conventional milk products and dropping all six of the

Table 2
Household variables

Variable	Mean	Std. Err	Min	Max
Household income (in dollars)	60,164	40,317	2,500	250,000
Household size (number of people)	2.23	1.17	1	9
Age of female head (in years)	55.99	10.31	22	68
Population density of the household residential area	1,547	5,056	0.76	70,924
Employment: = 1 if female head employed; = 0 if not	0.41	0.49	0	1
Education: = 1 if female head gained college education; = 0 if not	0.38	0.49	0	1
House: = 1 if owned house; = 0 if not	0.81	0.39	0	1
Single: = 1 if household size is 1; = 0 if not	0.27	0.44	0	1
Black: = 1 if household is African American; = 0 if other	0.08	0.28	0	1
Hisp: = 1 if household is Hispanic; = 0 if not	0.05	0.22	0	1
AgeC6: = 1 if presence of children 6 and below; = 0 if not	0.04	0.19	0	1
AgeC1317: = 1 if presence of children between 13 and 17; = 0 if not	0.10	0.29	0	1

The household income was converted to a continuous variable from 33 discrete categories using the mean of each category. For the highest category, $250K and above, we use $250K. Similarly, the age variable is converted to a continuous variable from the 29 discrete categories provided in the data.

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

organic milk products. Suppose γ_0 is the vector of all the parameter estimates for the subset model with the variance-covariance matrix Ω_0, and γ_1 is the vector of the associated parameter estimates with γ_0 for the full model with the variance-covariance matrix Ω_1. Then,

$$(6) \qquad \chi^2(r) = (\gamma_1 - \gamma_0)'(\Omega_1 - \Omega_0)^{-1}(\gamma_1 - \gamma_0)$$

has a chi-square distribution with the degrees of freedom *r* when IIA is true, where *r* is the rank of Ω_1- Ω_0. In our test, α^2 = 96.8 with 89 degrees of freedom. The 5-percent critical value for the test is 112, which implies that we cannot reject IIA at the 0.05 significance level.

For each of the 12 milk products, we then used the estimation results to calculate how much the probability of choosing each product would change with prices, promotional deals, income, household size, age, and other variables. Specifically, we calculated the elasticities of the choice probabilities. For the continuous explanatory variables, the elasticities are evaluated at the means of the explanatory variables and are best interpreted as the percentage changes in the probability of buying a particular milk product with a 1-percent change in the choice determinant. For the discrete explanatory variables, the elasticities are the percentage changes in the probability of buying a particular milk product when the discrete variable changes from 0 to 1. The standard errors of all elasticities were calculated from the Delta method proposed by Rao (1973). The results are reported in tables 3 to 5.

Income and Demographics

Households are hypothesized to switch from higher to lower priced milk products when their food budgets get tight. However, when incomes change, it is primarily the demand for organic milk products that is affected. Higher income households will purchase more organic milk (table 3). The largest increase in purchase probability is for low-fat, organic milk in a small container. On the one hand, buying less expensive products may help households with reduced incomes to afford a healthful

Table 3
Percentage changes in probability of purchasing fluid milk with respect to a 1-percent change in household variables

	Percentage changes in purchase probability						
	WHBC	RFBC	LFBC	WHSC	RFSC	LFSC	WHBO
HH ncome	-0.2315* (0.0063)	-0.1005* (0.0039)	0.0588* (0.0046)	-0.0941* (0.0060)	-0.0155* (0.0042)	0.1063* (0.0038)	0.0410 (0.1129)
HH size	0.7065* (0.0269)	0.5350* (0.0191)	0.1873* (0.0205)	-0.1750* (0.0279)	-0.3726* (0.0209)	-0.3892* (0.0184)	-1.3897* (0.6136)
Age	-0.3889* (0.0213)	-0.2343* (0.0158)	-0.1138* (0.0184)	-0.0688* (0.0213)	0.1162* (0.0175)	0.2490* (0.0168)	-2.6212* (0.3152)
Employment	0.0034 (0.0033)	-0.0098* (0.0022)	-0.0189* (0.0025)	0.0126* (0.0032)	0.0161* (0.0025)	-0.0002 (0.0021)	-0.1140 (0.0647)
Education	-0.0663* (0.0034)	-0.0302* (0.0022)	0.0345* (0.0022)	-0.0295* (0.0030)	-0.0074* (0.0022)	0.0334* (0.0018)	0.0023 (0.0613)
House	-0.0248* (0.0081)	0.0188* (0.0047)	0.0558* (0.0057)	-0.1003* (0.0070)	0.0078 (0.0054)	-0.0709* (0.0047)	-0.2782* (0.1068)
Single	0.1001* (0.0085)	0.0589* (0.0062)	0.0141* (0.0063)	-0.0561* (0.0077)	-0.0796* (0.0056)	-0.0707* (0.0050)	-0.4271* (0.1634)
Black	0.0224* (0.0012)	-0.0063* (0.0010)	-0.0582* (0.0019)	0.0319* (0.0009)	0.0148* (0.0007)	-0.0147* (0.0011)	-0.0028 (0.0211)
Hisp	0.0140* (0.0006)	0.0007 (0.0005)	-0.0036* (0.0006)	0.0049* (0.0007)	0.0050* (0.0005)	0.0015* (0.0005)	0.0219* (0.0092)
Popdensi	-0.0284* (0.0023)	-0.0403* (0.0016)	0.0032 (0.0016)	0.0041 (0.0023)	-0.0179* (0.0016)	0.0105* (0.0015)	0.1849* (0.0388)
AgeC6	0.0148* (0.0003)	0.0033* (0.0003)	-0.0013* (0.0005)	0.0073* (0.0006)	0.0017* (0.0007)	0.0015* (0.0006)	0.0134 (0.0106)
AgeC1317	-0.0024* (0.0010)	0.0008 (0.0006)	0.0052* (0.0007)	-0.0236* (0.0019)	-0.0098* (0.0012)	-0.0075* (0.0011)	0.0487* (0.0228)

—continued

Table 3
Percentage changes in probability of purchasing fluid milk with respect to a 1-percent change in household variables—continued

	Percentage changes in purchase probability				
	RFBO	LFBO	WHSO	RFSO	LFSO
HH income	0.6399* (0.0884)	0.4860* (0.0599)	0.2795* (0.0338)	0.2536* (0.0236)	0.4503* (0.0213)
HH size	0.9937* (0.2746)	0.4682* (0.2209)	-0.3246* (0.1268)	-0.1965 (0.1147)	-0.6767* (0.0831)
Age	-0.6132 (0.4762)	-1.2710* (0.1900)	-0.9245* (0.1097)	-0.9620* (0.0983)	-0.9654* (0.0774)
Employment	-0.0484 (0.0399)	-0.0715* (0.0303)	-0.0806* (0.0158)	-0.1112* (0.0136)	-0.0679* (0.0102)
Education	-0.0209 (0.0338)	0.1079* (0.0292)	0.0368* (0.0155)	0.0977* (0.0131)	0.0899* (0.0097)
House	0.4806* (0.2012)	0.1486 (0.0872)	-0.1821* (0.0325)	0.0018 (0.0364)	-0.1028* (0.0270)
Single	0.1715 (0.0986)	0.1334* (0.0677)	0.0581 (0.0399)	-0.0120 (0.0323)	-0.1540* (0.0238)
Black	-0.0257* (0.0146)	-0.0527* (0.0171)	-0.0059 (0.0072)	-0.0006 (0.0057)	-0.0234* (0.0051)
Hisp	-0.0034 (0.0099)	0.0003 (0.0075)	0.0054 (0.0033)	0.0114* (0.0024)	0.0086* (0.0022)
Popdensi	0.0870* (0.0405)	0.0622* (0.0198)	0.1226* (0.0103)	0.0259* (0.0107)	0.0964* (0.0079)
AgeC6	0.0186* (0.0072)	0.0082 (0.0043)	0.0419* (0.0020)	0.0050* (0.0024)	-0.0012 (0.0019)
AgeC1317	-0.0040 (0.0148)	-0.0053* (0.0103)	-0.0165* (0.0063)	-0.0095* (0.0050)	0.0109* (0.0035)

Notes: The figures in each row are the percentage changes in the probability of buying each of the 12 products (in the top row) following a 1-percent increase (or for dichotomous variables from 0 to 1) in each of the household variables (in the first column). Standard errors are in parentheses and "*" indicates significant at level of 0.05 or better.

WHBC = Whole, big (1 gallon), conventional; RFBC = Reduced-fat, big, conventional; LFBC = Low-fat, big, conventional; WHSC = Whole, small (less than gallon), conventional; RFSC = Reduced-fat, small, conventional; LFSC = Low-fat, small, conventional; WHBO = Whole, big, organic; RFBO = Reduced-fat, big, organic; LFBO = Low-fat, big, organic; WHSO = Whole, small, organic; RFSO = Reduced-fat, small, organic; LFSO = Low-fat, small, organic

Low-fat milk is defined as less than 2 percent fat including skim; *reduced-fat* is between 2 and 3.25 percent fat; and *whole* is at least 3.25 percent fat.

HH = Household; Age = age of female head; Popdensi = population density of the household residential area.

Employment: = 1 if female head employed; = 0 if not

Education: = 1 if female head gained college education; = 0 if not

House: = 1 if owned house; = 0 if not

Single: = 1 if household size is 1; = 0 if not

Black: =1 if household is African American; =0 if other

Hisp: = 1 if household is Hispanic; = 0 if not

AgeC6: = 1 if presence of children 6 and below; = 0 if not

AgeC1317: = 1 if presence of children between 13 and 17; = 0 if not

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

Table 4
Percentage changes in purchase probability with respect to a 1-percent increase in fluid milk prices

	Percentage changes in purchase probability											
	WHBC	RFBC	LFBC	WHSC	RFSC	LFSC	WHBO	RFBO	LFBO	WHSO	RFSO	LFSO
Price												
WHBC	**-0.6153**	0.1312	0.1575	0.0649	0.1112	0.1283	0.0005	0.0009	0.0019	0.0034	0.0056	0.0099
RFBC	0.0553	**-0.5140**	0.1492	0.0615	0.1054	0.1216	0.0005	0.0008	0.0018	0.0032	0.0053	0.0094
LFBC	0.0534	0.1202	**-0.4727**	0.0595	0.1018	0.1175	0.0005	0.0008	0.0017	0.0031	0.0051	0.0090
WHSC	0.0867	0.1951	0.2341	**-0.9050**	0.1653	0.1908	0.0007	0.0013	0.0028	0.0051	0.0083	0.0147
RFSC	0.0826	0.1858	0.2228	0.0920	**-0.7963**	0.1816	0.0007	0.0012	0.0027	0.0048	0.0079	0.0140
LFSC	0.0807	0.1816	0.2187	0.0899	0.1538	**-0.7543**	0.0007	0.0012	0.0026	0.0047	0.0077	0.0137
WHBO	0.0917	0.2062	0.2475	0.1021	0.1747	0.2017	**-1.0579**	0.0013	0.0029	0.0054	0.0088	0.0155
RFBO	0.0857	0.1928	0.2314	0.0953	0.1631	0.1885	0.0007	**-0.9880**	0.0028	0.0050	0.0082	0.0145
LFBO	0.0852	0.1916	0.2298	0.0948	0.1623	0.1874	0.0007	0.0012	**-0.9807**	0.0050	0.0082	0.0145
WHSO	0.1189	0.2674	0.3209	0.1324	0.2267	0.2615	0.0010	0.0017	0.0038	**-1.3659**	0.0114	0.0201
RFSO	0.1174	0.2642	0.3171	0.1308	0.2239	0.2583	0.0010	0.0017	0.0038	0.0069	**-1.3450**	0.0199
LFSO	0.1167	0.2625	0.3150	0.1300	0.2224	0.2566	0.0010	0.0017	0.0037	0.0068	0.0111	**-1.3276**

Notes: The figures in each row are the percentage changes in the probability of buying each of the 12 products (in the top row) following a 1-percent increase in each product's price (in the first column). All the elasticities are significant at the level of 0.05 or better.

WHBC = Whole, big (1 gallon), conventional; RFBC = Reduced-fat, big, conventional; LFBC = Low-fat, big, conventional ; WHSC = Whole, small (less than gallon), conventional; RFSC = Reduced-fat, small, conventional; LFSC = Low-fat, small, conventional; WHBO = Whole, big, organic; RFBO = Reduced-fat, big, organic; LFBO = Low-fat, big, organic; WHSO = Whole, small, organic; RFSO = Reduced-fat, small, organic; LFSO = Low-fat, small, organic

Low-fat milk is defined as less than 2 percent fat including skim; *reduced-fat* is between 2 and 3.25 percent fat; and *whole* is at least 3.25 percent fat.

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

diet. On the other hand, these households may be more exposed to further income decreases and/or price increases. To the extent that they are already purchasing less expensive items, they will have less room in their budgets to further economize. One exception is the fat content of milk. Consistent with Davis et al. (2010), we find a positive association between higher income and the probability of purchasing low-fat, conventional milk in a gallon container, which is the least expensive of all of our 12 products. Also, larger families are more likely to buy a big container of whole, conventional milk than a big container of whole, organic milk. However, household size appears to affect primarily the choice of container size. Not surprisingly, larger households tend to buy milk in larger packages.

The age of the female head of household is another important choice determinant. When people get older, they are more likely to buy reduced or low-fat conventional milk in a smaller container. Other research has shown that fluid milk consumption tends to decrease with age (e.g., Sebastian et al., 2010), suggesting that a gallon

Table 5
Percentage changes in purchase probability with respect to a 1-percent increase in use of fluid milk promotional deals

	Percentage changes in purchase probability											
	WHBC	RFBC	LFBC	WHSC	RFSC	LFSC	WHBO	RFBO	LFBO	WHSO	RFSO	LFSO
Deal												
WHBC	**0.1337**	-0.0285	-0.0343	-0.0141	-0.0241	-0.0279	-0.0001	-0.0002	-0.0004	-0.0007	-0.0012	-0.0021
RFBC	-0.0152	**0.1417**	-0.0413	-0.0169	-0.0290	-0.0335	-0.0001	-0.0002	-0.0005	-0.0009	-0.0014	-0.0026
LFBC	-0.0172	-0.0386	**0.1517**	-0.0191	-0.0327	-0.0377	-0.0001	-0.0003	-0.0005	-0.0010	-0.0016	-0.0029
WHSC	-0.0086	-0.0194	-0.0232	**0.0897**	-0.0164	-0.0189	-0.0001	-0.0001	-0.0003	-0.0005	-0.0008	-0.0014
RFSC	-0.0115	-0.0259	-0.0311	-0.0127	**0.1108**	-0.0253	-0.0001	-0.0002	-0.0004	-0.0007	-0.0011	-0.0019
LFSC	-0.0132	-0.0298	-0.0357	-0.0147	-0.0252	**0.1236**	-0.0001	-0.0002	-0.0004	-0.0008	-0.0013	-0.0022
WHBO	-0.0176	-0.0397	-0.0479	-0.0198	-0.0336	-0.0390	**0.2041**	-0.0002	-0.0006	-0.0011	-0.0017	-0.0030
RFBO	-0.0103	-0.0233	-0.0280	-0.0115	-0.0197	-0.0227	-0.0001	**0.1193**	-0.0003	-0.0006	-0.0010	-0.0018
LFBO	-0.0164	-0.0369	-0.0444	-0.0182	-0.0312	-0.0361	-0.0001	-0.0002	**0.1889**	-0.0010	-0.0016	-0.0028
WHSO	-0.0166	-0.0372	-0.0447	-0.0184	-0.0316	-0.0365	-0.0001	-0.0002	-0.0005	**0.1903**	-0.0016	-0.0028
RFSO	-0.0152	-0.0343	-0.0412	-0.0170	-0.0291	-0.0336	-0.0001	-0.0002	-0.0005	-0.0009	**0.1747**	-0.0026
LFSO	-0.0184	-0.0414	-0.0497	-0.0205	-0.0351	-0.0405	-0.0002	-0.0003	-0.0006	-0.0011	-0.0018	**0.2094**

Notes: The figures in each row are the percentage changes in the probability of buying each of the 12 products (in the top row) following a 1-percent increase in the use of deals to promote each product (in the first column). All the elasticities are significant at the level of 0.05 or better.

WHBC = Whole, big (1 gallon), conventional; RFBC = Reduced-fat, big, conventional; LFBC = Low-fat, big, conventional ; WHSC = Whole, small (less than gallon), conventional; RFSC = Reduced-fat, small, conventional; LFSC = Low-fat, small, conventional; WHBO = Whole, big, organic; RFBO = Reduced-fat, big, organic; LFBO = Low-fat, big, organic; WHSO = Whole, small, organic; RFSO = Reduced-fat, small, organic; LFSO = Low-fat, small, organic

Low-fat milk is defined as less than 2 percent fat including skim; *reduced-fat* is between 2 and 3.25 percent fat; and *whole* is at least 3.25 percent fat.

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

container may contain more milk than older household members can drink before it spoils. Regarding the influence of children in a household, the results show that presence of small children (6 years old or less) increases the probability of buying all types of milk besides conventional, low-fat milk in a 1-gallon container. However, the presence of teenagers between ages 13 and 17 has positive effects on the probability of buying organic, whole milk in a 1-gallon container, as well as conventional, low-fat milk in a 1-gallon container. That the effects differ depending on children's ages suggests that people may start to select different beverages in their early teenage years. Similar to past studies, we find a positive association between education and the demand for organic milk (e.g., Alviola and Capps, 2010), as well as a positive connection between education and the demand for lower fat milk products (e.g., Davis et al., 2010). Finally, when a household owns a house, it has a higher probability of buying either reduced-fat or low-fat milk in a 1-gallon container. Such households may have sufficient storage space in their homes to accommodate larger package sizes.

Price and Deal Variables

Prices and promotional deals can sway a household's choice among different milk products. Our results reveal that changing the price of any one of the 12 milk products affects the probability that a household buys that specific product (table 4). However, the magnitude of the response varies widely. Shown in bold along the diagonal elements of table 4 are each product's own-price effects. For example, if the price of conventionally produced whole milk sold in a gallon container increases by 1 percent, holding all other prices constant, then the probability of buying this product decreases by 0.62 percent. Own-price effects are significantly larger for organic milk products. Indeed, a 1-percent increase in the price of organically produced whole milk sold in a gallon container lowers the probability of buying this product by 1.06 percent. That is, the change in purchase probability is proportionally greater than the percentage change in the product's own price. In terms of fat content, we see that whole milk is most sensitive to own-price changes. In terms of container size, products sold in less-than-gallon packages are more sensitive to own-price changes. In general, the change in purchase probability is larger for more expensive products.

Our results also show that households switch to less expensive products when prices rise. Shown in the off-diagonal elements in table 4 are the cross-price effects. For example, holding all other prices constant, if the price of a gallon of conventionally produced whole milk increases by 1 percent, the probability of buying a gallon of conventionally produced low-fat milk increases by 0.16 percent. As shown in table 1, lower fat products tend to cost less than higher fat products. By contrast, an increase in the price of conventional milk sold in small containers primarily increases the probability that households buy the same type of milk in a gallon container. Finally, if the price of any one of the organic milk products increases, the probability that a household switches to conventional milk increases by more than does the probability the household buys another type of organic milk.

Our results show that promotional deals and increases in milk price have similar effects on purchase probabilities (table 5), but those effects are in opposite directions. In other words, promotional deals may work to counteract the effects of price changes.

In our analysis, an increased probability of buying one product—caused either by a change in price or the use of promotional deals—must decrease the probability of buying 1 or more of the 11 other milk products (tables 4 and 5). Indeed, the figures in each row of the 2 tables are the percentage changes in the probability of buying each of the 12 products following either a 1-percent increase in 1 product's price (table 4) or a 1-percent increase in the use of deals to promote that product (table 5). Because households must buy only 1 of the 12 products on any particular occasion when they buy milk, the figures in each row sum to zero.

Impact of Price and Income Shocks on Market Composition

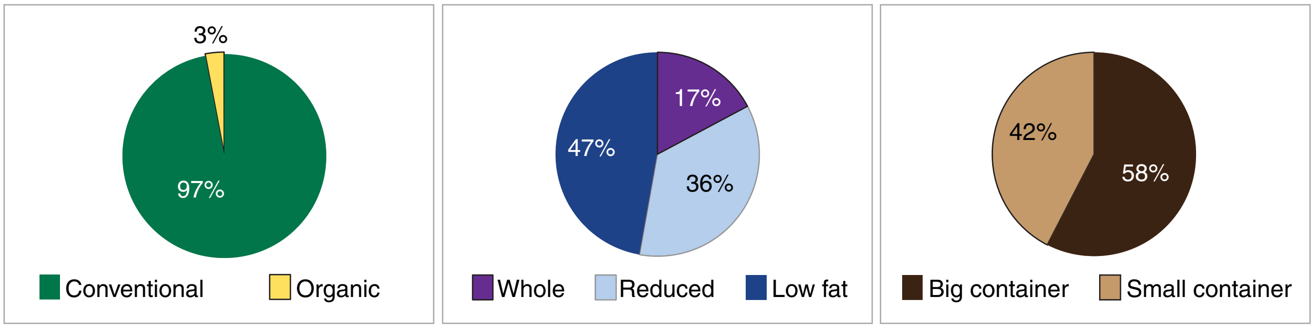
In the December 2007-June 2009 recession, prices increased for fluid milk and other staples. Kumcu and Kaufman (2011) show that, during that recession, consumers reacted by looking for ways to economize. We investigate how households adjusted their choices among fluid milk products. However, because many types of price and income shocks could again occur, we use our estimated model to simulate the effects of some possible future shocks. The elasticities in tables 3-5 are best interpreted as the percentage changes in the probability of buying a particular fluid milk product following 1-percent changes in income, price, and promotional deals, as well as changes to other variables. We now use these elasticities to predict changes in households' choices among all 12 fluid milk products in selected scenarios. Consider, for example, a 1-percent price increase for all products. To begin, because of the increase in that product's own price, we note that the probability of buying conventionally produced whole milk in a gallon container would decrease by 0.62 percent. At the same time, because of increases in the prices of the other 11 products, the same purchase probability increases by 0.06 percent, 0.05 percent, 0.09 percent, 0.08 percent, and so on. In total, summing the own-price and 11 cross-price effects in the first column of table 4, we find that the probability of buying conventionally produced whole milk in a gallon container increases by about 0.36 percent (table 6). Next, given the product's baseline market share of 8.8 percent (table 1), we estimate its new market share under the alternative scenario of a 1-percent general price increase. Though the new market share is very slightly higher, it is still roughly less than 9 percent (i.e., 0.088 + (0.0036 x 0.088)). After repeating this same series of steps for the other 11 products, we can aggregate over our predictions for each individual product to further estimate the re-division of fluid milk sales categorized by fat content, method of production, and package size. This would complete simulation results for a 1-percent increase in all fluid milk prices. Notably, we must repeat all calculations for other chosen scenarios. The process of calculating each product's new market share and aggregating over the predictions for all 12 products to estimate the re-division of the market categorized along three dimensions is a nonlinear process. For example, the impact of 10-percent price increase is not simply 10 times the impact of a 1-percent price increase. Finally, predictions derived for each scenario can be compared against the baseline scenario. Of all fluid milk purchased by U.S. households in 2007-08, 17 percent was whole, 47 percent was low-fat, and 36 percent was reduced-fat. Gallon packages accounted for about 58 percent of all purchases. Organic products represented about 3 percent of all sales. The results of the simulations are shown in tables 6 and 7. Some of the scenarios are also provided in figure 1.

Retail fluid milk prices tend to be volatile, as they fluctuate with prices that dairy farmers receive for milk (Stewart and Blayney, 2011). We examined monthly retail milk prices between 2000 and 2011[9] and find that retail prices typically change by 1 to 2 percent per month. However, retail prices are also highly cyclical. They can trend upward or downward for extended periods of time. The price of a gallon of fluid milk at the high and low points of a cycle can differ by 25 percent or more. To begin, in scenario 1 (fig. 1), we report the effects of a 1-percent increase in price for

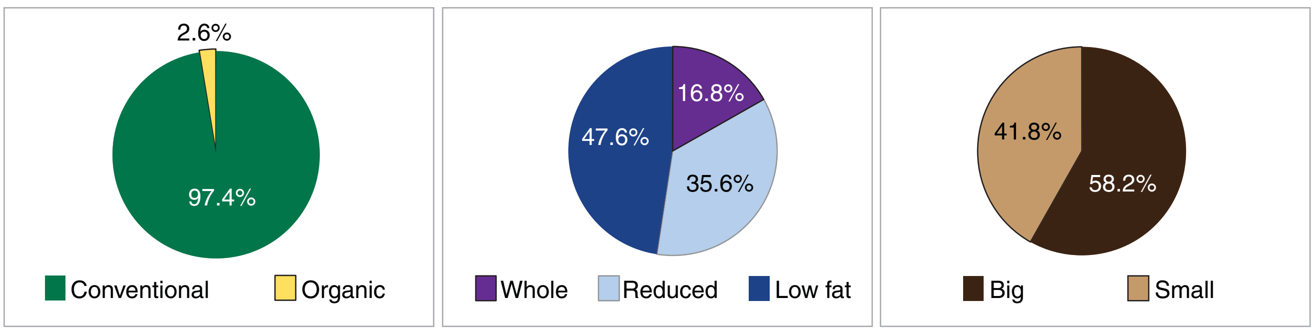
[9] Monthly retail prices for conventional whole and conventional reduced-fat milk published by the USDA AMS were examined. See AMS (2012).

Figure 1
Simulation results for several scenarios

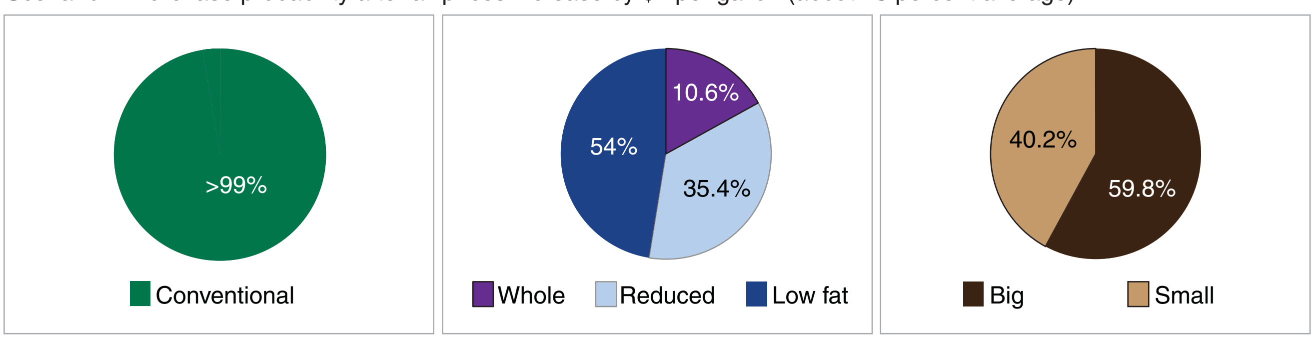
Baseline purchase probability:



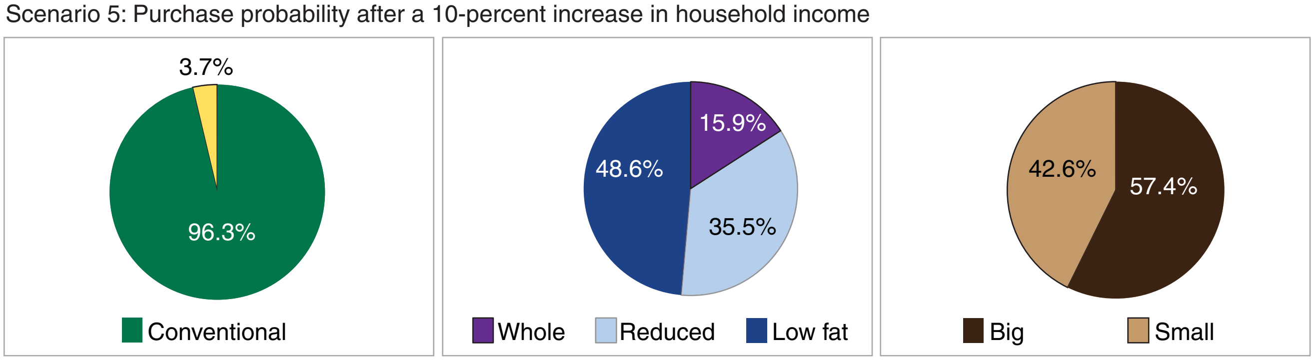
Scenario 1: Purchase probability after all prices increase by 1 percent



Scenario 2: Purchase probability after all prices increase by $1 per gallon (about 25 percent average)



Scenario 5: Purchase probability after a 10-percent increase in household income



Note: Simulations using model results. Retail milk products divided along three dimensions including method of production (organic and conventional), fat content (low-fat, reduced-fat, and whole), and container size (gallon or small-sized container).

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

Table 6
Percentage changes in probability of purchasing fluid milk with respect to a 1-percent change in household variables

	Percentage changes in purchase probability							
	1-percent increase of all milk prices	1-percent increase of organic milk prices	$1 increase of all milk prices	1-percent increase of all milk deal	1-percent increase of organic milk deal	1-percent increase of income	1-person increase of hhsize	1-year increase of age
WHBC	0.3590	0.6156	0.7520	-0.0400	-0.5220	-0.2315	0.3168	-0.0069
RFBC	1.6846	1.3847	25.2530	-1.3428	-1.1759	-0.1005	0.2399	-0.0042
LFBC	2.1713	1.6617	34.1143	-1.8164	-1.4140	0.0588	0.0840	-0.0020
WHSC	0.1482	0.6854	2.9480	-0.1579	-0.5823	-0.0941	-0.0785	-0.0012
RFSC	1.0143	1.1731	18.4712	-0.9902	-0.9962	-0.0155	-0.1671	0.0021
LFSC	1.3395	1.3540	24.2571	-1.2984	-1.1512	0.1063	-0.1745	0.0044
WHBO	-1.0499	-1.0535	-18.7373	1.0028	1.0070	0.0410	-0.6232	-0.0468
RFBO	-0.9742	-0.9804	-18.5919	1.0062	1.0140	0.6399	0.4456	-0.0110
LFBO	-0.9502	-0.9637	-18.2438	0.9742	0.9910	0.4860	0.2100	-0.0227
WHSO	-1.3125	-1.3368	-17.7120	0.9449	0.9754	0.2795	-0.1456	-0.0165
RFSO	-1.2574	-1.2973	-16.9845	0.8955	0.9447	0.2536	-0.0881	-0.0172
LFSO	-1.1724	-1.2431	-15.5195	0.8218	0.9085	0.4503	-0.3035	-0.0172
Conventional	6.7167	6.8746	105.79	-5.6455	-5.8410	-0.2765	0.2206	-0.0079
Organic	-6.7167	-6.8746	-105.79	5.6455	5.8410	2.1503	-0.5048	-0.1314
Total	0	0	0	0	0	1.8738	-0.2842	-0.1393

Note: First column of the table indicates the type of milk product, as follows: WHBC = Whole, big (1 gallon), conventional; RFBC = Reduced-fat, big, conventional; LFBC = Low-fat, big, conventional; WHSC = Whole, small (less than gallon), conventional; RFSC = Reduced-fat, small, conventional; LFSC = Low-fat, small, conventional; WHBO = Whole, big, organic; RFBO = Reduced-fat, big, organic; LFBO = Low-fat, big, organic; WHSO = Whole, small, organic; RFSO = Reduced-fat, small, organic; LFSO = Low-fat, small, organic

Low-fat milk is defined as less than 2 percent fat including skim; *reduced-fat* is between 2 and 3.25 percent fat; and *whole* is at least 3.25 percent fat.

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

Table 7
Simulation results for purchase probability

	Baseline	Scenario 1 1-percent increase of all milk prices	Scenario 2 $1 increase of all milk prices	Scenario 3 1-percent increase of organic milk prices	Scenario 4 10-percent increase of all milk deals	Scenario 5 10-percent increase of income	Scenario 6 1-person increase of hhsize	Scenario 7 1-year increase of age
	Purchase probability							
Conventional	97.0	97.4	100	97.4	90.0	96.3	97.0	97.0
Organic	3.0	2.6	< 1	2.6	10.0	3.7	3.0	3.0
1-gallon container	58.0	58.2	59.8	57.9	56.5	57.4	58.1	57.6
Small container	42.0	41.8	40.2	42.1	43.5	42.6	41.9	42.4
Whole	17.0	16.8	10.6	17.0	21.2	15.9	17.2	17.2
Reduced fat	36.0	35.6	35.4	35.6	35.8	35.5	35.7	35.6
Low fat	47.0	47.6	54.0	47.4	43.0	48.6	47.1	47.2
Total	100	100	100	100	100	100	100	100

Source: Calculated by authors using 2007-08 Nielsen Homescan data.

all milk products. Not surprisingly, as shown in the first two columns of numbers in tables 6 and 7 as well as in fig. 1, a 1-percent change in price has only small impacts on the composition of the fluid milk market.

The second scenario (table 7 and fig. 1) simulates the market share changes if prices for all 12 milk products rose, as in 2007-08. In those years, higher prices received by farmers for milk pushed retail prices for fluid milk as much as 25 percent higher (e.g., Stewart and Blayney, 2011). Although small shocks may have only small effects on the market, could such a large shock to prices motivate people to substitute, in significant quantities, less expensive products like conventional milk for more expensive products like organic milk? The elasticities are substantially less accurate when used to simulate much larger shocks, but may still serve as a very general indicator of whether market shares are likely to change only a little or a lot.

Following the same procedure outlined above, we find that milk price increases of $1 per gallon (approximately 25 percent) for all 12 products could slow growth in sales of organic milk, just as rising prices and the recession did between 2007 and 2009. By the simulation, the magnitude of the loss in organic market share could nearly equal the overall 2007-08 organic market share of 2 to 3 percent. We again caution that this estimate does not precisely measure the likely changes in market shares. However, the simulation does indicate that the impact on the organic market would be substantial. Likewise, the purchase probabilities decrease from 17 to 10.6 percent for whole milk; decrease from 36 to 35.4 percent for reduced-fat milk; and increase from 47 to 54 percent for low-fat milk. The probability of purchasing milk in a small container decreases from 42 to 40.2 percent, while the probability of buying it in a big container increases from 58 to 59.8 percent.

In the third scenario (table 7 and fig. 1), we consider the possibility that prices for organic and conventional milk products need not move together. Costs for feed and other inputs used exclusively by organic dairy farming could rise faster or slower than costs for inputs used by conventional dairy farmers. That may have been the case in 2011. Neuman (2011) reports that costs for organic farmers rose faster that year.

For the simulation, we consider the effect of a 1-percent increase in the price of the six organic products while holding constant prices for the six conventional products. Interestingly, the change in purchase probability for organic products is not much larger than the predicted impact of a 1-percent increase in the price of all milk products. This difference may reflect the fact that sales of organic products are more sensitive to price changes than sales of conventional products.

Promotional deals and price increases similarly affect a household's choice among milk products, although in opposite directions. To simulate the impact of promotional deals, we consider a 10-percent increase in promotions for all 12 milk products in scenario 4. Large increases in the probability of buying organic milk occur. In fact, the purchase probability for any one of the six organic milk products increases from 3 percent in the baseline scenario to 10.5 percent. This finding underscores the sensitivity of organic milk sales to both retail prices and the use of promotional deals.

For the final simulation, we consider the effects on market composition of shocks to income, as well as changes in household size and age. As shown in table 3, the effects of the latter two demographic variables are small but statistically significant. Rising income increases the probability of purchasing lower fat and organic products.

A 10-percent increase in household income raises the probability of purchasing organic milk from 3 to 3.7 percent. A 10-percent increase in income also lowers the probabilities of purchasing whole milk from 17 to 15.9 percent and reduced-fat milk from 36 to 35.5 percent. The probablility of buying low-fat milk increases from 47 to 48.6 percent. Only small changes occur to a household's choice among products in different container sizes. In contrast to household income changes, changes in household size and age have no effect on the probabilities of purchasing conventional and organic milk, but do affect substantially choice of container size (table 7).

Conclusions

During the December 2007 to June 2009 recession, many U.S. household experienced a decrease in income. In addition, food prices rose 4 percent in 2007 and 5.5 percent in 2008 before moderating to 1.8 percent in 2009. In this study, we examine some of the strategies that households use to stretch their food dollar in response to income and price shocks.

In particular, we focus on how they adjust their choice among fluid milk products categorized along three dimensions: three levels of fat content, two levels of package size, and organic versus conventionally produced products. Though fluid milk is a staple of the American diet, most Americans aged 4 and over do not consume enough dairy products.

Among the key results, households experiencing an income decrease substitute less expensive products for more expensive ones. The demand for organic milk is particularly sensitive to changes in income. Also, price fluctuations can influence a household's fluid milk purchases. In the recent past, retail milk prices have fluctuated by as much as 25 percent. A price increase of this magnitude has little impact on whether a household chooses to buy fluid milk in a 1-gallon or smaller sized container. It would decrease the probability that a household buys low-fat milk from 47 to 53.9 percent. Moreover, a 25-percent increase in retail fluid milk prices is large enough to reduce growth in sales of organic milk, as happened recently in 2007-08.

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Appendix I: The Specification of the Household Loyalty Variable (L_{ijt})

Households are heterogeneous with their own specific, seemingly idiosyncratic preferences among the products available at retail stores. These preferences may stay the same over time, but may also change based on households' purchase experience. For example, suppose that household A derives greater utility from product *i* than does household B at time *t*. If the two households face the same price and other variables are constant, the relative probability between the two households (i.e., the purchase probability for product *i* by household A is bigger than the one for household B) tends to remain the same for future purchases. However, if the households each gain more and more experience purchasing product *i*, they may adjust their purchase preferences over time, and the relative purchase probability for product *i* between the two households could be reversed. Fader and Lattin (1993) also point out that preferences can change with sudden, unforeseen occurrences. Household-specific preferences for given products are unobservable and are associated with household-specific demographic variables, as well as purchase experience. They are the household's intrinsic loyalty to the products it purchases. They are different from the observed purchase probabilities, which also depend on prices, promotional deals, and other marketing variables.

In this study, we follow Fader and Lattin (1993) and Dong and Stewart (2012) to define the loyalty probability (L_{ijt}) in equation (1) using the Dirichlet distribution and assume that the likelihood of a nonstationary change (a renewal) in the product loyalty probabilities for a given household between purchase occasions can be described by a Bernouli distribution. We then derive the expected product loyalty probabilities (i.e., the Dirichlet posterior probabilities) from the observed choice behavior of the household and use these posterior probabilities to form the basis of L_{ijt}.

Suppose that there are *J* products to choose from for a given household to buy milk at time *t*. Absent any information on households' income and demographic characteristics or their prior purchase history, we assume the prior probabilities of choosing each of the *J* products, $\rho_1, \rho_2 \cdots, \rho_j$, follow a Dirichlet distribution with parameters $\theta_1, \theta_2 \cdots, \theta_j$. The *pdf* of the Dirichlet distribution is

$$\text{(A1)} \quad D(\rho_1, \rho_2 \cdots, \rho_J) = \frac{\Gamma(\theta_1 + \theta_2 + \cdots + \theta_J)}{\Gamma(\theta_1)\Gamma(\theta_2)\cdots\Gamma(\theta_J)} \rho_1^{\theta_1 - 1} \rho_2^{\theta_2 - 1} \cdots \rho_J^{\theta_J - 1},$$

where $\Gamma(\cdot)$ is the gamma function, $\sum_{j=1}^{J} \rho_j = 1$, and all θs are positive. From equation (A1) we know

$$\text{(A2)} \quad E(\rho_j) = \frac{\theta_j}{\sum_{l=1}^{J} \theta_l},$$

where $E(\cdot)$ is expectation operation.

The θs are product-specific parameters that indicate the relative level of a household's preference for each product in the absence of any other information. Thus, equation (A2) gives the household initial choice (loyalty) probabilities to each of the products. However, according to Bayes Theorem, the probabilities can be updated at time t using a household's observed product choice history for milk purchases from time 1 through time t - 1, if these data are available. If we use y_{ijr} to represent household i's choice history, and define that y_{ijr} equals 1 if household i purchased product j at time r and equals zero otherwise, then we can update the probabilities given by equation (A1) using a new Dirichlet distribution with the parameters: $\theta_1 + \sum_{r=1}^{t-1} y_{i1r}, \theta_2 + \sum_{r=1}^{t-1} y_{i2r}, \cdots, \theta_J + \sum_{r=1}^{t-1} y_{iJr}$. Equation (A2) is updated for the new expected probability given the purchase history data , as the following:

$$\text{(A3)} \qquad E(\rho_{ijt} \mid y_{ijr}) = \frac{\theta_j + \sum_{r=1}^{t-1} y_{ijr}}{\sum_{l=1}^{J} \theta_l + t - 1},$$

where t - 1 is the total number of food purchases through time t -1 by household i. The model allows for household heterogeneity through $\sum_{r=1}^{t-1} y_{ijr}$, the observed household purchase history. To further capture heterogeneity caused by household demographics, we follow Dong and Stewart (2012) to extend the model through the parameterization of θ_j, using the vector of household variables, $\mathbf{Z_{it}}$:

$$\text{(A4)} \qquad \theta_{ijt} = e^{\gamma_{0j} + \boldsymbol{\gamma}_{1j} Z_{\mathbf{it}}},$$

where the parameters γ_{0j} and $\boldsymbol{\gamma}_{1j}$ are unique to each product. Age, income, household size, and other variables may be included in $\mathbf{Z_{it}}$ as past studies and economic theory suggest. The exponential specification of equation (A4) is to guarantee that θ_{ijt} is positive.

To allow for any sudden, unforeseen occurrences that might influence a household's product choices (for example, the entry and exit of a new brand, a new advertising campaign), we expand the Dirichlet probability formulation as a nonstationary process.

Nonstationarity in the Dirichlet choice model is assumed to be a renewal process. This renewal process may be described as follows: For any given time (purchase occasion), the household may renew its choice or loyalty probability because of sudden or unforeseen reasons with a probability of 1 - λ, where $0 \leq \lambda \leq 1$. As described by Fader and Lattin (1993), each renewal constitutes a new draw from the original Dirichlet distribution, restarts the purchase history from the renewal point until the next renewal, and is independent of previous renewals. Thus, the probability of k purchases elapsing without renewal since the last renewal is $(1 - \lambda)\, \lambda^k$, which is geometrically distributed, with λ being constant across households.

If a sudden, unforeseen event has changed a household's product choices, then only its behavior since that event provides useful information for predicting its current behavior. Given the nonstationary Dirichlet choice process for household *i* with an observed purchase history from occasions 1 to *t* - 1, the expected loyalty probability for product *j* at time *t* is given by

(A5) $$E(\rho_{ijt} \mid y_{ijr}) = \sum_{k=0}^{t-1} E(\rho_{ijt} \mid k) \cdot \delta_k,$$ with

(A6) $$E(\rho_{ijt} \mid k) = \frac{\theta_{ijt} + \sum_{r=t-k}^{t-1} y_{ijr}}{\sum_{l=1}^{J} \theta_{ilt} + k},$$ and

(A7) $$\delta_k = (1-\lambda)\lambda^k,$$

where $k = 0, 1, \cdots, t-1$; δ_k is the probability of *k* purchases elapsing without renewal since the last renewal; and y_{ijr} equals one if household *i* purchased product *j* at time *r*, and equals zero otherwise. When $k = 0$, we define $\sum_{r=t-k}^{t-1} y_{ijr} = 0$. θ_{ijt} is given in equation (A4), and λ is a parameter.

Allowing for household heterogeneity through both demographics and past purchase history, as well as possible nonstationarity, the specification of the household heterogeneity variable becomes

(A8) $$L_{ijt} = E(\rho_{ijt} \mid y_{ijr}) = \sum_{k=0}^{t-2} \varphi_{ijk}\delta_k + \varphi_{ijt-1}(1 - \sum_{k=0}^{t-2} \delta_k)$$

based on equation (A5), with $\varphi_{ijk} = E(\rho_{ijt} \mid k)$ as given in equation (A6) and δ_k as given in equation (A7).

Appendix II: Estimation Results

Our data appear to fit the model well. From the appendix table, we see that the predicted purchase probabilities for the 12 milk products are quite consistent with the data provided in table 1. Also, prices and promotional deals are significant at the 1-percent level. These marketing variables directly affect product choices and have the expected signs. Notably, given the specification of household utility in equation (1), these variables have the same coefficient (β) for all milk products. However, prices and promotions will still have different effects on the purchase probabilities for each product, in accordance with equation (4) for the variables' marginal effects (Dong and Stewart, 2012). The product-specific constants and some of the seasonal dummy variables are also significant at the 1-percent level. The constant and the coefficient on the seasonal dummy variable for the product *conventional, whole milk in a gallon container* were restricted to zero for the purpose of normalization, so that the values for all other products are relative to the value of this product. From equation (1), we see that household variables indirectly influence milk product choices through the household loyalty variable. Many of these variables are significant at the 1-percent level, including income, household size, age, and house ownership, among others. The effects of these variables on the purchase probabilities vary among milk products. Also significant is λ, the nonstationary probability associated with the loyalty variable. It indicates how often a household's product choices are influenced by sudden, unforeseen occurrences, such as a new promotional marketing campaign. A value near one indicates that such events rarely occurred.

Appendix table: **Model estimates**

Variable	WHBC	RFBC	LFBC	WHSC	RFSC	LFSC
Probability:	0.0866	0.1948	0.2338	0.0964	0.1651	0.1905
Household Variables:						
Intercept	3.6185* (0.1242)	2.2020* (0.1115)	-3.0533* (0.1273)	-0.4436* (0.1474)	-2.416* (0.1252)	-5.6751* (0.1178)
Log HH income	-0.4046* (0.0114)	-0.2107* (0.0089)	0.1214* (0.0107)	-0.1788* (0.0119)	-0.0355* (0.0099)	0.2278* (0.0091)
Inverse HHsize	-1.8928* (0.0833)	-1.7144* (0.0714)	-0.5351* (0.0791)	0.7059* (0.0980)	1.5431* (0.0870)	1.6437* (0.0790)
Age	-0.0133* (0.0007)	-0.0096* (0.0006)	-0.0052* (0.0008)	-0.0032* (0.0008)	0.0035* (0.0007)	0.0089* (0.0007)
Employment:	0.0071 (0.0144)	-0.0567* (0.0121)	-0.1055* (0.0142)	0.0503* (0.0155)	0.0749* (0.0141)	-0.0095 (0.0126)
Education	-0.2654* (0.0148)	-0.1322* (0.0122)	0.2160* (0.0136)	-0.1185* (0.0145)	-0.0176 (0.0129)	0.2174* (0.0118)
House	-0.0707* (0.0186)	0.0317* (0.0136)	0.1302* (0.0168)	-0.2509* (0.0173)	0.0023 (0.0159)	-0.2107* (0.0139)
Single	0.4248* (0.0507)	0.2113* (0.0420)	0.0696 (0.0449)	-0.5438* (0.0552)	-0.7905* (0.0482)	-0.7368* (0.0439)
Black	0.5798* (0.0267)	0.0029 (0.0230)	-0.9382* (0.0356)	0.8941* (0.0258)	0.5029* (0.0189)	-0.1755* (0.0242)
Hisp	0.6030* (0.0226)	0.1193* (0.0240)	-0.0664* (0.0267)	0.2726* (0.0282)	0.3066* (0.0223)	0.1491* (0.0229)
Popdensi	-0.0570* (0.0043)	-0.0923* (0.0037)	-0.0011 (0.0038)	0.0002 (0.0047)	-0.0466* (0.0037)	0.0147* (0.0037)
AgeC6	1.0973* (0.0195)	0.4731* (0.0242)	0.1451* (0.0329)	0.5987* (0.0355)	0.2941* (0.0391)	0.2787* (0.0314)
AgeC1317	-0.0661* (0.0204)	-0.0007 (0.0208)	0.1191* (0.0225)	-0.4599* (0.0359)	-0.2199* (0.0267)	-0.1733* (0.0230)
Marketing variables and other parameters:						
Constant	0	-0.0004 (0.0133)	0.1521* (0.0148)	0.2106* (0.0371)	0.1712* (0.0324)	0.2630* (0.0310)
Spring	0	-0.0548* (0.0184)	-0.1272* (0.0203)	0.1455* (0.0198)	0.1378* (0.0200)	0.0953* (0.0207)
Summer	0	-0.0155 (0.0205)	-0.1310* (0.0230)	0.1678* (0.0223)	0.1950* (0.0227)	0.0937* (0.0235)
Fall	0	-0.0347 (0.0278)	-0.2012* (0.0304)	0.1157* (0.0288)	0.0713* (0.0297)	-0.0573 (0.0309)
Milk price	-0.1888* (0.0205)					
Milk deal	1.0121* (0.0724)					
λ	0.9963* (0.0110)					
Log likelihood	-479,127.99					

—continued

Appendix table: **Model estimates—continued**

Variable	WHBO	RFBO	LFBO	WHSO	RLSO	LFSO
Probability:	0.0007	0.0013	0.0028	0.0051	0.0083	0.0146
Household Variables:						
Intercept	-5.9509* (2.1401)	-15.5443* (1.5161)	-11.9883* (1.0309)	-9.7030* (0.5970)	-7.7794* (0.4234)	-11.992* (0.3630)
Log HH income	0.0577 (0.1650)	0.9360* (0.1297)	0.7122* (0.0882)	0.4110* (0.0501)	0.3762* (0.0354)	0.6759* (0.0323)
Inverse HHsize	3.6611* (1.5713)	-2.4464* (0.7054)	-1.0996* (0.5690)	-0.9458* (0.3291)	0.6192* (0.3008)	1.8930* (0.2208)
Age	-0.0696* (0.0083)	-0.0169 (0.0126)	-0.0344* (0.0050)	-0.0253* (0.0029)	-0.0266 (0.0026)	-0.0269* (0.0021)
Employment:	-0.4180 (0.2336)	-0.1816 (0.1446)	-0.2660* (0.1108)	-0.3007* (0.0578)	-0.4168* (0.0502)	-0.2593* (0.0381)
Education	0.0255 (0.2306)	-0.0622 (0.1279)	0.4270* (0.1113)	0.1577* (0.0593)	0.3945* (0.0509)	0.3707* (0.0383)
House	-0.5252* (0.1961)	0.8713* (0.3712)	0.2600 (0.1615)	-0.3529* (0.0605)	-0.0114 (0.0685)	-0.2094* (0.0515)
Single	-2.3133* (0.8327)	0.7376 (0.5038)	0.5435 (0.3463)	0.1598 (0.2063)	-0.2024 (0.1682)	-0.9503* (0.1261)
Black	0.0636* (0.3374)	-0.3034 (0.2339)	-0.7337* (0.2737)	0.0149 (0.1175)	0.1004 (0.0942)	-0.2725* (0.0832)
Hisp	0.7175* (0.2728)	-0.0326 (0.2927)	0.0767 (0.2233)	0.2317* (0.1000)	0.4140* (0.0745)	0.3357* (0.0692)
Popdensi	0.2668* (0.0574)	0.1226* (0.0601)	0.0861* (0.0295)	0.1769* (0.0154)	0.0325* (0.0162)	0.1403* (0.0120)
AgeC6	0.7192 (0.4347)	0.9457* (0.3012)	0.5158* (0.1812)	1.9312* (0.0835)	0.3871* (0.1005)	0.1274 (0.0815)
AgeC1317	0.7440* (0.3565)	-0.0796 (0.2331)	-0.1002 (0.1629)	-0.2785* (0.0993)	-0.1682* (0.0798)	0.1587* (0.0561)
Marketing variables and other parameters:						
Constant	-0.6639* (0.1280)	-0.5398* (0.0699)	-0.2341* (0.0632)	0.3530* (0.0814)	0.2164* (0.0762)	0.4907* (0.0722)
Spring	0.2284 (0.1432)	-0.0776 (0.0999)	-0.0347 (0.0835)	0.2897* (0.0670)	0.3056* (0.0510)	0.1197* (0.0434)
Summer	0.3212* (0.1396)	0.2462* (0.1030)	0.2518* (0.0895)	0.2195* (0.0752)	0.3821* (0.0586)	0.1632* (0.0478)
Fall	0.9846* (0.1496)	1.1154* (0.1095)	0.6669* (0.1090)	0.2169* (0.0905)	0.4104* (0.0746)	0.1006 (0.0625)
Milk price	-0.1888* (0.0205)					
Milk deal	1.0121* (0.0724)					
λ	0.9963* (0.0110)					

—continued

Appendix table: **Model estimates—continued**

Variable	WHBO	RFBO	LFBO	WHSO	RLSO	LFSO
Log likelihood	-479,127.99					

Source: Calculated by authors using 2007-08 Nielsen Homescan data. Notes: Standard errors are in parentheses. The constant and the coefficient of grocery stores in the marketing variables are constrained to be zero. "*"indicates significant at level of 0.05 or better.

WHBC = Whole, big (1 gallon), conventional; RFBC = Reduced-fat, big, conventional; LFBC = Low-fat, big, conventional ; WHSC = Whole, small (less than gallon), conventional; RFSC = Reduced-fat, small, conventional; LFSC = Low-fat, small, conventional; WHBO = Whole, big, organic; RFBO = Reduced-fat, big, organic; LFBO = Low-fat, big, organic; WHSO = Whole, small, organic; RFSO = Reduced-fat, small, organic; LFSO = Low-fat, small, organic. Low-fat milk is defined as less than 2 percent fat including skim; reduced fat is between 2 and 3.25 percent fat; and whole is at least 3.25 percent fat. HH = Household; Age = age of female head; Popdensi = population density of the household residential area. Employment: = 1 if female head employed, = 0 if not; Education: = 1 if female head gained college education, = 0 if not; House: = 1 if owned house, = 0 if not; Single: = 1 if household size is 1, = 0 if not; Black: =1 if household is African American, =0 if other; Hisp: = 1 if household is Hispanic, = 0 if not; AgeC6: = 1 if presence of children 6 and below, = 0 if not; AgeC1317: = 1 if presence of children between 13 and 17, = 0 if not.