# Do Voluntary Biotech Labels Matter?  Evidence from the Fluid Milk Market

by

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## ABSTRACT

This paper models and assesses the effects on demand of voluntary labeling for the use of genetically modified growth hormone for retail fluid milk using supermarket scanner data. Retail fluid milk is of interest because (1) it tracks one of the first biotech products approved, (2) fluid milk is fairly standardized and ubiquitous, and (3) this market enables cross sectional differentiation between labeled and unlabeled products and between conventional and organic brands. The hypothesis that voluntary biotech-free labels increase consumers' willingness to pay is supported. These estimated effects are both statistically and economically significant, and appear to increase over time.

*Keywords:* biotech, random utility, scanner data, search, voluntary labeling

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### Introduction

Innovations through biotechnology enable agricultural producers to reduce production costs and/or enhance product quality for many livestock and crop commodities. At the same time, however, these innovations may affect the demand for the products that utilize those commodities. Many individuals, for example, are concerned about potential risks to human health although by no means all consumers have such concerns (Burton, Metcalfe, and Smith; Heiman, Just, and Zilberman). The use of the recombinant Bovine Growth Hormone (rBGH) in milk production has been a particular concern for some consumers as approximately one third of the United States dairy herd, about 3 million dairy cows, currently receive rBGH supplements (Monsanto).

Product labeling, particularly with respect to the provision of health and environmental information, is increasingly being used to provide information about product characteristics such as biotechnology content that cannot otherwise be observed (Teisl and Roe). There is no clear international policy consensus about whether biotechnology labeling should be mandatory or voluntary. The United States supports voluntary labeling while the European Union supports mandatory labeling and just recently tightened their mandatory labeling regulations (Der Spiegel). In this context, quantitative evidence about the effects of labeling on the consumption of biotechnology food products provides policy relevant information about the economic value of labeling to agricultural producers, food processors, and consumers.

Previous studies of the effects of labeling have presented theoretical analyses of the possible effects of voluntary labeling on consumer demand, in some cases in the context of household production models (Smallwood and Blaylock; Caswell and Padberg; Teisl and Roe; Golan, Kuchler, and Mitchell). Teisl and Roe have emphasized the role of cognitive abilities, information, and time in defining the specific process by which labeling information is translated into consideration of product attributes and Teisl, Roe and Hicks have adjusted Stigler and Becker's model of advertising to incorporate labeling effects on consumer knowledge about product attributes on the demand for a product. The theoretical model of the effects of labeling presented in the next section of this paper is innovative in that it sets a representative consumer's information search decision within a random utility specification of a household production model that reflects the uncertain nature of product information both in the absence and presence of labeling. The model provides clear predictions about the impact of increased labeling on the demands for a product that has a desirable but costly to observe characteristic.

This study investigates the predictions of this model by econometrically examining the effects of voluntary labeling about the use of biotechnology on aggregate fluid milk consumption in major U.S. markets. The U.S. fluid milk market provides an appealing case study for examining the effects of biotechnology labeling for several reasons. First, rBGH has been used in U.S. milk production since 1994, providing one of the earliest examples of the use of biotechnology in food production.[1] Thus, it is possible to incorporate some longitudinal data into the analysis of consumption behavior, a facet that is especially important since market adjustments to labeling initiatives appear to occur slowly over time (Teisl, Roe, and Hicks). Second, fluid milk is a relatively standardized and ubiquitous processed commodity. Third, and perhaps most importantly, U.S. fluid milk consumption patterns involve product differences with respect to rBGH-free unlabeled, labeled, and organic products, and conventional fluid milk products that include milk from dairy cows receiving rBGH supplements. National-level supermarket scanner data for the period 1995-1999 compiled by Information Research, Inc. (IRI) provide quantitative information on these consumption patterns. These data, made available to the authors through a cooperative agreement with the USDA Economic Research Service, are combined with new information on product brands compiled by the authors to create a data set that can be used to estimate the effects of voluntary labeling on U.S. milk consumption patterns.

Previous empirical studies of the effects of food product labeling have tended to focus on the provision of nutrition information. Ippolito and Mathios found that nutritional labeling had significant effects on consumer choices. However, Mojduszka and Caswell, in a test of Grossman's model of voluntary quality signaling, suggested that voluntary labeling information provided by firms is incomplete and not necessarily reliable. Teisl, Bockstael, and Levy used supermarket purchase data to assess changes in consumer behavior due to increased nutritional labeling. They reported that consumer's purchase behavior was significantly altered, but purchases of "healthy" goods increased only in some, not all, food product categories.

Empirical studies of the effects of labeling on milk demand are mainly limited to the analysis of survey responses (McGuirk, Preston, and Jones; Grobe and Douthitt;

Misra and Kyle). Aldrich and Blisard utilized monthly pooled time series and regional (cross section) data for the period 1978 to 1996 to examine whether the introduction of rBGH milk reduced aggregate fluid milk consumption, but found no evidence of such an effect. The econometric results using scanner data presented in this paper indicate that voluntary labeling does affect the composition of milk consumption in important ways and that these effects do not diminish over time.

Retail supermarket scanner data used for this study presents an otherwise effectively absent set of information for purposes of demand estimation of specific products on a wide geographic scale. This retail scanner data provides price and quantity data from actual purchases, rather than from relatively expensive hypothetical survey or experimental data. Additional secondary information can be obtained that permits identification of the products' labeling specifications. This data does offer some modeling challenges, including (1) aggregation across consumers, precluding the use of income or other demographic variables, (2) the effective preclusion of specific data on desired firm decisions such as advertising expenditures on the product, shelf footage and placement, and production cost information, and (3) some products are offered nationally, while others are offered only regionally. Although these considerations impose some caveats in the interpretation of the results presented below, the use of retail scanner data allows estimation and testing of the effects of voluntary rBGH-free labels on consumer demand.

**Theoretical Model**

The model presented in this section incorporates the key elements of product attribute models (Becker; Rosen) with those of advertising and search models (Stigler; Stigler and Becker; Teisl and Roe; and Teisl, Roe and Hicks) within a random utility framework (McFadden; Thompson and Kidwell; Mathios) to account for the effects of labeling on consumer choice over milk products. We assume that consumers receive utility from milk produced without rBGH through subjective evaluation of health risks, environmental impacts, and consideration of their ethical beliefs. Additional product label information regarding these attributes facilitates more accurate assessments by consumers of product attributes related to these concerns.

The level of search over product attributes is integrated as a choice variable in a random utility framework. The randomness in utility arises from uncertainty about product attributes. This uncertainty can be reduced by search. Here, as in many information search models, an increase in the market share of products with the desired attributes, labeling information about these attributes, and previously acquired human capital each reduce the variance of the random component.

To focus on the choice between different fluid milk products, the constrained utility maximization problem is defined using a random utility function where E[−] denotes the expectation operator over a random term r:

(1) $$\max_{\underline{x},\underline{m},t} \; E[U(\underline{x},\underline{m},r)] \; subject\ to\ Y=\sum_{i=1}^{n} p_i x_i + \sum_{j=1}^{k} p_j m_j + wt.$$

The vector $\underline{x}$ includes all consumption goods except fluid milk products and the vector $\underline{p}$ represents market prices of these commodities. Consumption from among the $k$ specific brands of fluid milk is denoted by $\underline{m}$, where milk brand $j$ is purchased at price $p_j$. The household selects search time ($t$) over milk products and their prices, where the opportunity cost of search time is $w$ per unit (hour). For reasons of clarity, the household is assumed to search only on two attributes, the absence of the genetically modified Bovine Growth Hormone (rBGH), and product prices.

To simplify the exposition, consider an environment in which only two branded milk products, $m_1$ and $m_2$, are available. Product $m_1$ denotes the rBGH-free milk product and $m_2$ denotes an unlabeled conventional product that contains milk from cows treated with rBGH. Suppose, for modeling purposes, that each consumer purchases either brand $m_1$ or brand $m_2$, but not both. The absence of rBGH in $m_1$ and the use of rBGH in $m_2$ is not known to the consumer with certainty, so the consumer's choice between $m_1$ and $m_2$ is modeled through random components $r^1$ *and* $r^2$, drawn from a distribution $R(\mu, \sigma^2(L,H,t))$. The variance of the random component is assumed to be inversely related to labeling information ($L$), previously acquired human or consumption capital ($H$) that reflects the consumer's information set, and search time ($t$).

The representative household's potential benefits from search over the properties of $m_1$ and $m_2$ are stochastic. This stochasticity arises because consumers are unsure about the rBGH status of the milk products and they are *ex ante* uncertain about the utility differences between consuming $m_1$ and $m_2$, defined through:

(2) $$E\left[U\left(\underline{x}, m_1, r^1\right) - U\left(\underline{x}, m_2, r^2\right)\right] = \delta$$

Equation (2) defines the expected difference in utilities for a given household between consuming $m_1$ and $m_2$, holding constant the choice of $\underline{x}$, the vector of consumption goods. This expected utility difference is assumed to vary across consumers because of differences in consumer information, the amount of search undertaken, and differences in perceptions of health risks, environmental concerns and in ethical beliefs. For purposes of prediction, $\delta$ is assumed to be positive. Note that as $\delta$ approaches zero, the consumer approaches a state of indifference between $m_1$ and $m_2$.

Given that second order derivatives are satisfied for the constrained maximization problem, optimal values for the choice variables $\underline{x}$, $\underline{m}$, and $t$ can be found and the following equation can be derived using the dual of equation (2):

(3) $$U\left(\underline{x}^*, m_1^*, r^1\right) - U\left(\underline{x}^*, m_2^*, r^2\right) = V^*\left(Y, \underline{p}, w, \mu, L, H\right)$$

In (3), $V^*$ denotes the stochastic indirect utility difference function. Given equation (3), the probability that milk product $m_1$ will be selected over $m_2$ is:

(4) $$P\left(V^* > 0\right) \equiv P\left(m_1 > 0\right).$$

The following prediction can be derived from this framework by differentiating equation (4) with respect to labeling of product $m_1$ ($L$), where labeling is defined as a continuous variable:[2]

(5) $$\frac{\partial P(m_1 > 0)}{\partial L} \equiv \frac{\partial P(V^* > 0)}{\partial V^*} * \frac{\partial V^*}{\partial L} > 0$$

In this context, labeling is modeled as a continuous variable to emphasize the possibility of an increase in the quality of labeling information. Both terms on the right-hand side of equation (5) can be signed for households that have a positive $\delta$. The probability that $V^*$ is greater than zero increases with the mean of $V^*$. *Ceteris paribus*, for consumers with $\delta > 0$ an increase in the amount of labeling information about the use of rBGH increases $V^*$ through a reduction in the variance of $r^1$. This mean preserving reduction in spread in the cumulative density functions for $V^*$ is illustrated in figure 1 for a qualitatively large change in labeling. The cumulative density function for $V^*$ in the absence of product labeling is denoted by $CDF_{no\ label}$, and $CDF_{label}$ represents the cumulative density function when milk is labeled as rBGH-free.

In practice and to the extent that it is measurable, labeling information is often discrete. For example, rBGH-free milk may be unlabeled (*L1*), or it may be voluntarily labeled as rBGH-free (*L2*). Another labeling regime entails certification by an independent agency, as is the case for labeled organic milk products (*L3*), although additional factors such as concerns about pesticide residue or support for organic farming might also increase the probability that a product will be chosen by a consumer. The increased "quality" of labeling increases the likelihood that the purchased milk product will be $m_1$; that is:

(6) $$P(m_1 > 0 | L1) < P(m_1 > 0 | L2) < P(m_1 > 0 | L3).$$

If income effects are relatively small, Marshallian demand functions will not differ significantly from Hicksian demand functions. Small income elasticities for fluid milk estimated in previous studies (e.g., Heien and Wessels) suggest that own-price effects for branded fluid milk products are likely to be negative for the Marshallian demand functions derived from this model. Inequality (6) represents the primary prediction that will be investigated empirically using retail scanner data.

Additional information that increases human capital regarding rBGH will influence the likelihood of purchase in a manner analogous to the effect of labeling changes in equation (5). For example, new reliable scientific information that portrays rBGH negatively (positively) in regard to health and environmental risks would increase (decrease) the stochastic difference in utilities ($V^*$) through a decrease in uncertainty. While this predicted probability increase (decrease) could occur with or without additional labeling information, a change in $H$ is also likely to alter the labeling effect. Labeling becomes more (less) valuable to consumers as their expected difference in utilities changes. Additionally, advocacy by scientists in favor of biotechnology such as that called for in Beachy could lead to reduction in the labeling effect over time.

**Data**

National-level supermarket scanner data for fluid milk demand were combined with information about the use of rBGH in milk production and product specific labeling to evaluate labeling effects.[3] Over 13,000 supermarkets, either belonging to national chains or operating independently, that were located in 64 U.S. metropolitan areas, were tracked by Information Resources, Inc. (IRI).[4] Quantities sold and prices were initially tracked over 13-week periods from January 1995 to December 1997 and then over 4-week periods from January 1998 to December 1999. The sales quantities collected by IRI were aggregated across the 64 metropolitan areas at the product code (UPC) level. Prices were temporally aggregated (first within the initial 13-week tracking period and then over the 4-week week period) and spatially aggregated and were based on list prices that did not take advertised sales into account.

The analysis focuses on branded beverage milk, excluding buttermilk and flavored milk and only considers half-gallon and gallon containers. In each product category, prices for milk sold under supermarket owned brand labels (e.g., Safeway and Albertsons store brands) are aggregated to obtain a reference brand price to which the prices of other milk brands with different biotechnology characteristics are compared. Aggregate nationwide supermarket sales include sales of milk under the supermarkets' own labels as well as branded milk in all container sizes, including quarts, pints, etc. The data set does not allow the computation of market share with respect to branded milk alone. According to Thompson and Glaser branded milk accounted for about 1/3 of supermarket milk volume sales over the time period investigated in this study.

Prices and unit sales for 202 different branded fluid milk products offered by 13 different milk processors were obtained from the IRI database and combined with information about the use of rBGH in milk production and the milk processor's labeling practice during the period of 1995-1999. Approximately 10% of fluid milk in the US was labeled rBGH-free during this period. Products included in the analysis were selected as follows. First, firms that process rBGH-free milk were identified using a comprehensive list complied by *Rural Vermont* and *Mothers and Others* (Purefood) and additional information regarding retail milk markets to contact processors. The authors then conducted a survey of those milk processors. Thirteen processors provided sufficiently reliable information about the use of rBGH and labeling characteristics to be included in the analysis. These 13 firms are estimated to have jointly had a 3.9% market share for skim and low fat milk sales and a 2.4% market share for whole fat milk sales in supermarkets nationwide over the sample period. The firms run the gamut from those with brands available nationwide to smaller regional processors; the set of firms also offers fairly wide geographic coverage of the U.S. milk market. Two of the 13 processors sold rBGH-free milk that was not labeled as such, seven sold fluid milk products that were labeled as rBGH-free, three sold organic milk products, and five sold conventional milk products.[16] Three milk processors produce items in more than one category such as organic and conventional milk products.

None of the 13 processors changed their policy with regard to rBGH use or labeling over the period 1995-1999. Four categories of branded milk products—conventional, unlabeled rBGH-free, labeled rBGH-free, and organic—were available in supermarkets over the entire time period. However, organic milk products sold in gallon containers were not included in the data set until April 1998. The categorical data on rBGH-characteristics at the product level obtained in the survey of milk processors were coded using three mutually exclusive zero-one dummy variables (*rBGHfreenonlabeled*, *rBGHfreelabeled,* and *organic*). Comparison of means tests indicated that price differences were statistically significant at less than the 1% level for every fat content and container size category between (a) products labeled rBGH-free products and conventional products, and (b) between products labeled rBGH free and rBGH-free products that were not labeled. Milk products labeled rBGH-free were sold at premiums over conventional milk products that ranged from 41 to 47 cents for half-gallons and 34 to 49 cents for gallons. Similarly, organic milk products were also generally sold at premiums over conventional milk products that ranged from 98 cents to $1.16 for half-gallons and $1.81 to $2.49 for gallons. Converting these premiums to percentages of the conventional prices yields a range from a 26 to 30% price premium for rBGH-free labeled milk in half-gallons and a 13 to 17% price premium for rBGH-free labeled milk in gallons. Organic milk prices, however, were 63 to 75% higher than conventional milk prices for half-gallons and 65 to 90% higher than conventional milk prices for gallons. Non-labeled rBGH-free milk products did not generally sell at a premium over conventional branded milk products in this data set.

A market size variable (*marketsize*) was constructed that accounts for differences in the size of the market served by the 13 milk processors in the data set. Annual population estimates for the period 1995 to 1999 reported by the U.S. Census Bureau for states in which the product was available were used to capture the number of potential consumers (in millions) for a given milk product.

The data were organized into eight different fat content and container size categories to permit comparisons of clearly homogeneous products. For instance, demand functions for whole milk products in gallon containers are estimated separately from demand functions for 2% milk in gallon containers and for categories of milk in half-gallon containers. As noted above, a reference brand was defined within each fat content and container size category, and two additional variables, the logarithm of quantity ratios between each milk product and its reference brand and the price difference between each milk product and its reference brand, were computed. The price and quantity data for the reference brands used in this computation consist of nationwide unit sales averages and price averages of supermarket owned labels that include milk produced with rBGH but do not have labels that indicate this fact to consumers. The aggregate nature of the reference brand data precludes it from serving as an instrument for differences in the size of market served by a specific brand; the market size variable discussed previously was used to instrument for these market sales differences.

The data set used in the econometric analysis consists of 5,840 observations. Each observation corresponds to a specific fluid milk product identified by its UPC that was sold nationwide in a specified time period. Between 1995-1997 these observations were collected for 13-week periods. However, in 1998 the data collection procedure changed, with observations from 1998-1999 collected for 4-week tracking periods, and not all products are recorded in all time periods. Table 1a provides descriptive statistics for the variables included in the data set where each observation records the relative unit sales, price and other information for a single brand during a single tracking period. Table 1b provides market share data for fat content and container size categories of fluid milk products.

**Econometric Specification**

The representative individual's random utility model in Section II provides important predictions about the effects of rBGH-free labeling. Two implications for estimations follow from the IRI data used in this study. First, the IRI data set records aggregate (nationwide, across all consumers) purchase quantities of each branded milk product over a number of weeks. Second, milk purchases at the individual level for the multi-week periods used here are also not “lumpy” in the McFadden sense because consumers are likely to have multiple purchases within each period. The dependent variable in the estimation models, therefore, is effectively continuous, and so a discrete choice econometric framework is not required.

Additional assumptions are placed on the indirect utility function in (3) and on the error distribution to operationalize the model developed in Section II for the available data. The representative consumer’s indirect utility difference function presented in its general form in equation (3) for purchase and consumption of fluid milk product $m_i$ over multiple milk products, is assumed to be linear; that is:[5]

$$(7) \qquad V_i^* = (A_i\beta + \varepsilon_i) - (A_j\beta + \varepsilon_j) \qquad \textit{for all} \quad j \neq i$$

In equation (7), the vectors $A_i$ and $A_j$ indicate the attributes of milk brand $m_i$ and all alternative milk brands $m_j$, and the vector $\beta$ represents the weights the household places on each of these attributes. The error term in equation (7) is assumed to arise from randomness in attribute perception. As indicated in equation (4) for the two product case, purchase and consumption of fluid milk product $m_i$ over alternative milk products indicates that:

$$(8) \qquad E\left[(A_i\beta + \varepsilon_i) - (A_j\beta + \varepsilon_j)\right] > 0 \qquad \textit{for all} \quad j \neq i.$$

Under an *iid* logistic distributional assumption, the probability that the *i*th fluid milk product ($m_i$) is purchased can then be written as:

$$(9) \qquad P(m_i > 0) = \frac{\exp(A_i\beta)}{\sum_{j=1}^{n} \exp(A_j\beta)},$$

where $exp(\bullet)$ denotes the exponential function and $j = 1, 2, \ldots, n$ denotes all available milk products.

For uniformity of brand comparisons, the regressions make use of private-label supermarket milk sales as a reference brand for all milk sales. The relative odds of the representative consumer choosing product $m_i$ over the reference brand, $m_r$, is:

$$(10) \qquad \frac{P(m_i > 0)}{P(m_r > 0)} = \frac{\exp(A_i \beta)}{\exp(A_r \beta)}$$

The aggregate quantity ratios are consistent estimates of the likelihood ratios in equation (10). Redefining the left-hand side variable as unit sales of product *i* divided by unit sales of a reference brand, and taking its logarithm, equation (10) can be written as a linear function of the parameters for estimation; that is,

$$(11) \qquad \ln\left(\frac{unitsales_{m_i}}{unitsales_{m_r}}\right) = \left(A_i - A_r\right)\beta.$$

Equation (11) forms the basis for the estimation equations used in the empirical analysis. In this formulation, the vector $(A_i\text{-}A_r)$ denotes differences in attributes between the *i*th fluid milk product and the reference brand. Here, the key component of this attribute difference vector is the information about whether a brand is produced with or without the use of rBGH, or organic. This process characteristic is interacted with the information about product labeling. Not all of the processors sell milk produced without the use of rBGH label their products as rBGH free, while all of the organically produced milk products are labeled organic. The information on prices in the data set is expressed as the difference in the price of milk product $m_i$ and the price of the reference brand.

Demand differences resulting from attributes such as fat content and container size are allowed for in the estimations through separate regression equations for each one of the four fat contents (skim, 1%, 2%, and whole) and the two container sizes (half gallons and gallons). Each of these regression equations include an error term due to error in the data collection process such as due to aggregation or to abstraction from specific time of purchase information such as sales or promotions.

An important prediction of the theoretical model (equation (6)) is that milk products labeled as rBGH-free are more likely to be chosen by consumers who, *ceteris paribus*, have a positive difference in utility between rBGH-free and conventional milk. The magnitude of the coefficient for unlabeled rBGH-free products is predicted to be smaller than the magnitude of the coefficient for labeled rBGH-free products due to search costs and, intuitively, the coefficient for unlabeled rBGH free milk may not be significantly different from zero.

The coefficient for the organic milk products dummy variable is predicted to be positive and of greater magnitude than the coefficient for rBGH-free and labeled products. Organic milk production is certified by independent third parties and must meet standards set by individual states or new national standards. Organic milk therefore represents an increase in the quality of labeling over voluntary rBGH-free labeling by a processor. Additional factors such as concerns over pesticide residues or support of organic farming might also increase some household preferences for organic products. In addition, uncertainty about utility differences and the prediction with regard to availability of new reliable scientific information would result in either a decrease or increase of the coefficient for rBGH-free labeled milk products.

Econometric models of fluid milk demand were estimated separately for each fat content (fat-free, 1%, 2%, and whole) and container size (half-gallons and gallons) to allow for varying levels of substitutability between these products. Sample sizes for each fat content and container specific estimation consisted of more than 300 observations.

*Diagnostics*

There may have been some important structural changes in the fluid milk data over the estimation period (1995-1999). Data on organic fluid milk in gallons were included in the data set beginning only in April 1998, with subsequent steady increases in aggregate sales. Additionally, the data-reporting period changed from a 13-week to a 4-week period in 1998. Chow tests (Chow) were conducted to investigate evidence of structural change in the market in 1998. Absence of structural change was rejected as the null hypothesis at conventional levels for approximately 50% of the fat content/container size categories. The regression results reported below therefore include models estimated for the two sample sub-time periods 1995-97 and 1998-99 to permit comparisons across all products with respect to evidence of structural change. Parameter estimates for the split samples do not in fact differ greatly from estimates based on the entire sample.

Several tests for heteroskedasticity were performed on the data set. The general Breusch/Pagan test indicated the presence of heteroskedasticity for all fat content levels and container sizes. Restricted tests that related the error structure to specific explanatory variables failed to reject the null hypothesis (White). Heteroskedasticity in the data appears to be introduced by a number of factors that cannot be easily separated. Consequently, all regression models were estimated in a Generalized Least Squares (GLS) form and White-corrected standard errors are reported. Finally, no significant autocorrelation problems were detected in the sample.

The firms included in the analysis comprise less than 5% of nationwide supermarket fluid milk sales in the IRI database. Thus the fluid milk supply curve from dairy farmers to these relatively small segments of the fluid milk market for branded products (conventional, rBGH-free, organic) is expected to be relatively price elastic. The derived retail fluid milk supply curves may not be so price elastic. Price/quantity relationships for retail supply that relate to the costs of monitoring and enforcing rBGH-free labels are of particular interest. These costs are generally incurred at the milk processing firm level, and may differ across firms. Although we do not have useful measures for firm-specific costs for fluid milk supply at the retail level, we instrument for them in the estimated demand models through firm-specific dummy variables for the 13 milk processors included in the sample.

Several alternatives to the instrumental variables approach are available that differ in the treatment of firm-specific effects, including fixed effect models. Fixed effects models of demand were estimated without instrumenting for firm cost effects. These models yielded very similar qualitative results to the instrumental variables approach. There were also generally no significant improvements in model fit when a random effects approach was utilized. Parameter estimates based on the instrumental variables approach are reported because of their potential to account for firm-specific costs differences in monitoring and enforcement for rBGH-free labels as well as advertisement.

**Regression Results**

Results for the instrumental variables regression models are presented in tables 2-5 for the two sample time periods (1995-1997 and 1998-1999) and for each fat content and container size combination. Estimated coefficients for price difference variables are negative and statistically significant for almost all fat content and container size combinations and in both time periods. These coefficient estimates range from -2.89 to -4.50 for half-gallons and from -1.00 to -3.54 for gallons, indicating that the logarithm of the ratio of the quantity of its sales to the quantity of sales of the reference brand is inversely related to the price difference between that product and the reference brand.

Estimates for the *marketsize* variable coefficients are positive and significant in most regressions, suggesting that, *ceteris paribus*, as the potential market for a product increases, sales increase relative to the reference brand. This result is consistent with the hypothesis that there are economies of scale associated with serving larger markets.

The parameter estimates for *rBGHfreelabeled* are of central interest in this study. For the first time period (1995-1997), these coefficients are both positive and statistically significant for only two products, fat free and whole milk in gallons. For the second period (1998-1999), when the data were collected, over more frequent intervals, parameter estimates are significant and positive in three quarters of the regressions (six out of eight cases). Coefficient estimates for rBGH-free labeled milk range from .56 to .87 for half-gallons and from .90 to 1.57 for gallons. These results are consistent with the predictions of the theoretical model. They indicate that, *ceteris paribus*, by reducing information search costs labeling improves the quality of information about product characteristics and increases consumption of milk labeled rBGH-free. The estimated coefficients for the labeling variables are potentially affected by an omitted variables bias in the data set because information about advertising expenditures on specific products, promotional sales, and shelf placement could not included simply because it could not be observed. However, it should be noted that firm-specific dummy variables were included in the estimation models to at least partially account for the effects of these omitted variables.

The differences in the coefficient estimates for the two time periods suggest that over time consumers may alter the degree of which they adjust their purchase decisions in response to changes in labeling policies, in this case increasing their purchase of rBGH-free milk. It should be noted that the difference in estimated coefficients might be associated with the change in the frequency with which the data were collected in 1998. In contrast to some claims, however, there is no evidence that consumer preferences for rBGH-free milk have declined over the period in response to publicly provided scientific information that rBGH milk has few, if any, harmful health effects.

Table 6 presents quantity ratios, quantities and differences computed at the sample means to assess the *rBGHfreelabeled* effect. While the changes in the ratios are relatively small, quantities almost double for product categories where this coefficient is statistically significant.

No consistent results were obtained with respect to the dummy variable for rBGH-free products that were not labeled as such. The estimated coefficients for *rBGHfreenonlabeled* in tables 2-5 are either negative and significant, or positive and significant, or insignificant across fat content and container size categories and time periods and exhibit no discernable pattern. These results indicate that the provision of relevant information on a product label may be required if market segmentation is to take place between conventional and rBGH-free products. However, the small number of firms (2) that sell rBGH-free but unlabeled milk products may mean that these coefficients are also capturing the effects of unobservable variables such as advertising expenditures, promotional sales and shelf life not accounted for by the firm specific dummy variables.

Parameter estimates for the organic fluid milk dummy variable are generally positive and significant, ranging from 1.83 to 4.10 for half-gallons and 1.28 to 3.81 for gallons. Parameter estimates for gallons could only be obtained for the second time period (1998-1999) because organic milk sold in gallon containers did not appear in the data set until April 1998. These parameter estimates are greater in magnitude than the estimates for rBGH-free labeled variable, a finding consistent with the prediction of the theoretical model presented above. While additional factors such as concerns over pesticide residues or support of organic farming might increase preferences for organic products, the magnitude of these coefficients may also be influenced by market penetration of organic milk products. An increasing number of supermarkets added organic products to their product palette over the estimation period resulting in steadily increasing sales in the data set.[6]

The parameter estimates reported in tables 2-5 indicate that increased labeling alters the milk consumption decisions of some consumers. Thus, while it is not feasible to obtain quantitative estimates for the welfare effects of labeling with the information available, these results suggest that increased labeling enhances consumer welfare.

The empirical model specifications also permit the computation of aggregate own price demand elasticity estimates for rBGH-free labeled and conventional fluid milk.[7] Table 7 presents the own price elasticity estimates for rBGH-free labeled and conventional milk for the second time period.[8] Both of these categories include only branded milk products and the own price elasticity estimates reported here are specific to fat levels and container sizes. These elasticity estimates range from -0.002 to -0.28 for rBGH-free labeled milk in half-gallons and -0.12 to -0.95 in gallons, and from -0.14 to -2.35 for conventional milk in half-gallons and -0.00002 to -1.57 in gallons. Note that these elasticity estimates are subject to the caveat that the data set does not allow inclusion of demographic data or expenditure data, nor do the elasticity estimates include prices of potential substitution goods (e.g., soymilk or milk products outside the sample). While some of the elasticity estimates are smaller in absolute magnitude than previously reported price elasticities, in the aggregate, the results do not differ markedly from previous studies (e.g., Glaser and Thompson; Green and Park; Gould; Heien and Wessells; Teisl, Bockstael, and Levy). The elasticity estimates as a whole suggest no clear pattern in response to price changes between rBGH-free labeled and conventional milk. If only the estimated price elasticities for gallon milk products are considered, consumers appear more responsive to price changes in rBGH-free labeled milk than in conventional milk, but for half-gallon products, there is little evidence of similar effects. It is important to note, however, that differently labeled fluid milk products appear to have different price elasticities of demand.

**Conclusion**

This study is innovative in several respects. A household production model of the effects of labeling has been developed that explicitly accounts for both search costs and uncertainty about product attributes and information within a random utility framework. A clear implication of this model is that the provision of additional positive information will, *ceteris paribus*, increase consumption of the commodity with a desirable but costly to observe characteristic and reduce consumption of a competing commodity with an undesirable characteristic.

The predictions of the model were tested utilizing a new data set on actual purchases of fluid milk produced using rBGH and rBGH-free milk. The econometric results of the study indicate that, *ceteris paribus*, the provision of labeling information increases the quantity demanded of rBGH-free branded milk, a result consistent with the predictions of the theoretical model. These results also confirms the findings of previous studies based on surveys of consumer attitudes (but not consumer behavior in the market place) which indicate that some consumers have preferences for milk and other foods that are not produced with biotechnology. Finally, these results suggest that increased labeling, holding prices constant, results in increased consumer welfare. Whether or not total economic welfare increases is unclear, as we do not have sufficient information to compare benefits of labeling with its costs.

Another interesting result is that this study provides no evidence that consumer preferences for rBGH-free milk products have diminished since the introduction of rBGH milk products. If anything, the positive effects of labeling on the demand for rBGH-free fluid milk appear to have increased in the period 1998-1999 as compared to the period 1995-1997. This suggests that those who postulate that consumer concerns over biotech products will diminish over time in response evidence about the lack of adverse health effects may be wrong.

The results of the study are also important in that the findings indicate that own price elasticities of demand for different categories of fluid milk are substantially different. While the elasticity estimates reported here are similar to those reported for aggregated fluid milk demand in other studies, they do differ between conventional milk and milk labeled as rBGH-free.

One limitation of this study derives from the aggregate nature of the scanner data used in the empirical analysis. Aggregation to the national level, an unavoidable requirement given the available data set, precludes any evaluation of regional and household demographic and socioeconomic variables that affect consumption choices. An important extension of this study would be to develop and analyze time-series/cross-section panel data sets that track individual households over sufficiently long time periods to investigate the evolution of consumer attitudes and market choices with respect to biotech products and biotech labeling. Another limitation is that the results might be influenced by omitted variables that are practically not possible to include such as product specific advertising, shelf placements, and promotional sales. Notwithstanding these limitations, this study provides the first estimates we know of about the impact of biotech labeling on actual retail purchases of a food product.

**ENDNOTES**

[1] The FDA approved rBGH for general use in November 1993 but, in response to consumer concern, Congress placed a moratorium on its use until February 1994 (Aldrich and Blisard).

[2] Income effects from an increase in labeling are assumed to be zero in this derivation, although provision of labeling information may decrease search time for some households.

[3] A cooperative agreement with the U.S. Department of Agriculture (USDA) and Economic Research Service (ERS) provided access to a commercial database.

[4] IRI uses the food industry's definition of a supermarket: A grocery store with dairy, produce, fresh meat, package food, and non-food departments and annual sales of $2 million or more. Sales from health food stores, food cooperatives, or natural food stores are not included.

[5] The focus of this analysis is the choice of fluid milk brands based on their attributes. This focus, plus the assumption that the choice of $\underline{x}$ will be unchanged for different

indirect utility functions, allows suppressing a constant term that relates to other goods consumed in this specification.

[6] A model specification that added an interaction term between *organic* and the year the data was used to control for market penetration did not yield significantly different estimates and F-tests did not indicate improved explanatory power in most regressions.

[7] The following regression was estimated using an instrumental variables approach:

$$\ln\left(\frac{unitsales_{mi}}{unitsales_{mr}}\right) = \alpha_0 + \alpha_1 marketsize + \beta_1 rBGHfreelabeled + \beta_2 (P_{mi} - P_{mr}) rBGHfreelabeled + \beta_3 (P_{mi} - P_{mr}) conventional.$$

The price difference and rBGH-characteristic interaction terms were instrumented using the same exogenous variables as in the primary model. Carrying out appropriate transformations, price elasticities for rBGH-free labeled milk can be derived as follows: $\eta = unitsales_{mr} * e^{\beta_2 P_{mi}} * \beta_2 * \frac{P_{mi}}{unitsales_{mi}}$. For conventional milk, the same equation is used, substituting $\beta_3$ for $\beta_2$.

[8] Price elasticity measures were only computed if $\beta_2$ and/or $\beta_3$ were statistically significant in the regression specification. For the first time period a number of the coefficients were insignificant, making comparisons between the elasticities impossible. In addition, the data entries for the two rBGH-free non-labeled brands do not provide sufficient price variation between brands to investigate price elasticities and market penetration of organic milk products over the estimation period, resulting in positive coefficients for an interaction term between price differences and the organic characteristic.

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**Table 1a. Descriptive Statistics**

| Variable | Obs. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| $unitsales_{mi}$ | 5840 | 137,490 | 220,847 | 1 | 2,030,569 |
| $unitsales_{mr}$ | 312 | 8,351,017 | $1.18*10^7$ | 988,116 | $6.56*10^7$ |
| ln ($unitsales_{mi}$/ $unitsales_{mr}$) | 5840 | -4.90 | 2.36 | -14.91 | -1.29 |
| $P_{mi}$ | 5840 | 2.22 | .75 | .95 | 5.51 |
| $P_{mr}$ | 312 | 2.03 | .47 | 1.36 | 2.87 |
| $P_{mi}$-$P_{mr}$ | 5840 | .31 | .53 | -.89 | 3.01 |
| marketsize | 5840 | 130.33 | 103.61 | 12.58 | 272.70 |
| rBGHfreenonlabeled | 5840 | .08 | .28 | 0 | 1 |
| rBGHfreelabeled | 5840 | .28 | .45 | 0 | 1 |
| organic | 5840 | .13 | .34 | 0 | 1 |

**Table 1b. Market Share of Fluid Milk Products across Fat Content and Container Size**

| | Observations | Mean unit sales | % of total unit sales |
|---|---|---|---|
| half-gallon | 3666 | 119,006 | 54.34 |
| fat free | 1019 | 134,538 | 17.07 |
| 1% | 926 | 90,250 | 10.44 |
| 2% | 902 | 144,884 | 16.28 |
| whole | 816 | 103,743 | 10.24 |
| Gallon | 2174 | 168,660 | 45.67 |
| fat free | 665 | 151,659 | 12.56 |
| 1% | 388 | 142,955 | 6.90 |
| 2% | 572 | 223,691 | 15.94 |
| whole | 549 | 150,083 | 10.26 |

**Table 2. Regression Results for Half-gallon, Fat Free, and 1% Milk Relative Quantities**

| Independent variable | fat free | | 1% | |
|---|---|---|---|---|
| | 1995-1997 | 1998-1999 | 1995-1997 | 1998-1999 |
| Constant | -4.02*** | -4.27*** | -3.75*** | -4.27*** |
| | (.23) | (.09) | (.14) | (.08) |
| marketsize | .001 | .0005 | .004*** | .002*** |
| | (.001) | (.0006) | (.0008) | (.0006) |
| $P_{mi}$-$P_{mr}$ | -.89 | -3.13*** | -3.33*** | -2.89*** |
| | (.96) | (.33) | (.73) | (.21) |
| rBGHfreenonlabeled | -.59 | -1.67*** | -2.44*** | -1.60*** |
| | (.39) | (.34) | (.32) | (.24) |
| rBGHfreelabeled | -.29 | .56*** | .10 | .87*** |
| | (.34) | (.20) | (.23) | (.17) |
| organic | .33 | 3.81*** | -.15 | 1.83*** |
| | (.97) | (.42) | (1.01) | (.43) |
| Sample size | 309 | 710 | 257 | 672 |
| Degrees of freedom | 303 | 704 | 251 | 666 |
| F-statistic | 1.34 | 28.32 | 41.94 | 72.25 |

Note: Standard errors are corrected for heteroskedasticity and reported in parentheses. *, **, and *** denote coefficients that are statistically different from 0 at the 10%, 5% and 1% level.

**Table 3. Regression Results for Half-gallon, 2%, and Whole Milk Relative Quantities**

| Independent variable | 2% | | Whole | |
|---|---|---|---|---|
| | 1995-1997 | 1998-1999 | 1995-1997 | 1998-1999 |
| constant | -3.67*** | -4.62*** | -4.49*** | -4.39*** |
| | (.18) | (.16) | (.23) | (.11) |
| marketsize | .001 | .003*** | .003*** | .001* |
| | (.001) | (.0007) | (.001) | (.0008) |
| $P_{mi}$-$P_{mr}$ | -3.88*** | -3.39* | -4.50*** | -3.96*** |
| | (.59) | (.28) | (.71) | (.30) |
| rBGHfreenonlabeled | -2.90*** | -2.02*** | -1.89*** | -2.71*** |
| | (.46) | (.38) | (.51) | (.44) |
| rBGHfreelabeled | -.16 | .66*** | .08 | .17 |
| | (.21) | (.18) | (.30) | (.17) |
| organic | 2.15*** | 3.85*** | 2.61*** | 4.10*** |
| | (.69) | (.38) | (.83) | (.39) |
| Sample size | 301 | 601 | 251 | 565 |
| Degrees of freedom | 295 | 595 | 245 | 559 |
| F-statistic | 15.24 | 43.01 | 12.89 | 46.45 |

Note: Standard errors are corrected for heteroskedasticity and reported in parentheses. *, **, and *** denote coefficients that are statistically different from 0 at the 10%, 5% and 1% level.

**Table 4. Regression Results for Gallon, Fat Free, and 1% Milk Relative Quantities**

| Independent variable | fat free | | 1% | |
|---|---|---|---|---|
| | 1995-1997 | 1998-1999 | 1995-1997 | 1998-1999 |
| constant | -6.59*** | -7.04*** | -4.05*** | -3.61*** |
| | (.32) | (.17) | (.47) | (.12) |
| marketsize | .005*** | .005*** | .004*** | .001 |
| | (.002) | (.0009) | (.002) | (.0009) |
| $P_{mi}$-$P_{mr}$ | -3.54** | -2.97*** | -2.87*** | -3.05*** |
| | (.68) | (.27) | (1.05) | (.41) |
| rBGHfreenonlabeled | 2.01*** | 2.09*** | -.61 | -1.41*** |
| | (.31) | (.17) | (.85) | (.30) |
| rBGHfreelabeled | 1.41*** | 1.21*** | .31 | .26 |
| | (.47) | (.28) | (.42) | (.23) |
| organic | _ | 3.05*** | _ | 2.37* |
| | | (.69) | | (1.37) |
| Sample size | 184 | 481 | 121 | 267 |
| Degrees of freedom | 179 | 475 | 116 | 261 |
| F-statistic | 74.93 | 144.39 | 9.21 | 26.55 |

Note: Standard errors are corrected for heteroskedasticity and reported in parentheses. *, **, and *** denote coefficients that are statistically different from 0 at the 10%, 5% and 1% level.

**Table 5. Regression results for Gallon, 2%, and Whole Milk Relative Quantities**

| Independent variable | 2% | | whole | |
|---|---|---|---|---|
| | 1995-1997 | 1998-1999 | 1995-1997 | 1998-1999 |
| constant | -5.35*** | -5.22*** | -4.78*** | -4.47*** |
| | (.41) | (.21) | (.31) | (.21) |
| marketsize | .005*** | .005*** | .003*** | .003** |
| | (.001) | (.001) | (.001) | (.0007) |
| $P_{mi}$-$P_{mr}$ | -1.00* | -2.49*** | -1.69*** | -2.52*** |
| | (.52) | (.27) | (.54) | (.29) |
| rBGHfreenonlabeled | .78 | .48 | -.09 | -1.04*** |
| | (.71) | (.41) | (.49) | (.33) |
| rBGHfreelabeled | -.13 | .90*** | .96*** | 1.57*** |
| | (.34) | (.25) | (.33) | (.22) |
| organic | _ | 1.28** | _ | 3.81*** |
| | | (.56) | | (.66) |
| Sample size | 183 | 389 | 164 | 376 |
| Degrees of freedom | 178 | 383 | 159 | 371 |
| F-statistic | 6.50 | 48.23 | 4.01 | 25.46 |

Note: Standard errors are corrected for heteroskedasticity and reported in parentheses. *, ** and *** denote coefficients that are statistically different from 0 at the 10%, 5% and 1% level.

**Table 6. Economic Significance Computed at the Sample Means**

| fat content, container size category | time period | $unitsales_{mi}/unitsales_{mr}$ (rGBHfreelabel=0) | $unitsales_{mi}/unitsales_{mr}$ (rGBHfreelabel=1) | difference | $unitsales_{mi}$ (label=0) | $unitsales_{mi}$ (label=1) | difference |
|---|---|---|---|---|---|---|---|
| fat free, half-gallon | 1998-99 | 0.0081 | 0.0142 | 0.0061 | 67,810 | 118,712 | 50,903 |
| fat free, gallon | 1995-97 | 0.0010 | 0.0042 | 0.0032 | 8630 | 35,346 | 26,717 |
| fat free, gallon | 1998-99 | 0.0012 | 0.0040 | 0.0028 | 9824 | 32,943 | 23,120 |
| 1%, half-gallon | 1998-99 | 0.0083 | 0.0197 | 0.0115 | 69,048 | 164,811 | 95,764 |
| 2%, half-gallon | 1998-99 | 0.0072 | 0.0138 | 0.0066 | 59,688 | 115,484 | 55,796 |
| 2%, gallon | 1998-99 | 0.0059 | 0.0145 | 0.0086 | 49,141 | 120,867 | 71,726 |
| whole, gallon | 1995-97 | 0.0073 | 0.0191 | 0.0118 | 60,948 | 159,179 | 98,230 |
| whole, gallon | 1998-99 | 0.0117 | 0.0562 | 0.0445 | 97,712 | 469,669 | 371,957 |

Note: Values are reported only if the coefficient for *rBGHfreelabel* was statistically significant.

**Table 7. Price Elasticities Computed at the Sample Means**

| | | 1998-1999 | |
|---|---|---|---|
| | | rBGH-free labeled | conventional |
| half-gallon | | | |
| | fat free | -.28 | -.14 |
| | 1% | -.002 | -.68 |
| | 2% | -.14 | — |
| | whole | -.05 | -2.35 |
| gallon | | | |
| | fat free | -.95 | -.00002 |
| | 1% | -.36 | -.0002 |
| | 2% | -.56 | -.0004 |
| | whole | -.12 | -1.57 |

Note: Estimated price elasticities reported in the table are significant at the 1% significance level, except for the half-gallon, 2% conventional that is significant at the 5% significance level.

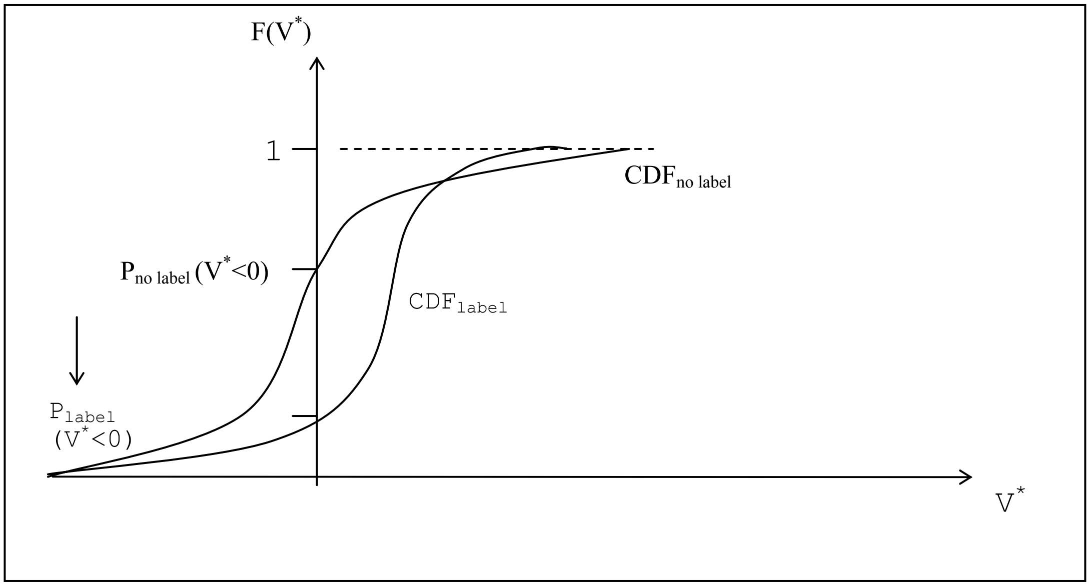


**Figure 1. Cumulative density functions for V*.**