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Milk by Any Other Name…

Consumer Benefits from Labeled Milk

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Abstract
This article uses revealed preferences of consumers to study the consumer benefits from rBST-free and organic labeled milk. The article specifies and estimates a quadratic AIDS demand system model for different milk types using US supermarket scanner data. The introduction of rBST-free and organic milk is used to estimate consumer benefits, which are decomposed into two components, competitive and variety effects. Results show significant consumer benefits from organic milk and to a lesser extent from rBST-free milk. Based on the findings, we explore implications for present U.S. labeling standards.

Keywords: Biotechnology, Demand Systems, Labeling, Milk, Organics, Retailing, Q-AIDS

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The U.S. food sector is going through rapid transformations in terms of new product introduction and innovations. Organic and genetically modified (GM) food products are leading the way in changing the landscape of available choices to consumers. This rapid expansion of product space has taken place concomitantly with an increase in public policy concerns on issues of standardization, labeling, health risks and associated consumer welfare. In this paper we explore these broader issues in the context of a specific product introduction, the introduction of rBST (recombinant bovine somatotropin)-free and organic milk in the U.S. market. From a policy perspective understanding the market for organics and the various components of that demand, i.e., what portion is for GM free and what is for other attributes of organics, can help determine the value of creating a national standard and the potential welfare losses to consumers of weakening such a standard. Are consumers willing to pay extra for organic and rBST-free milk? If so, how much are they willing to pay? What is the value or cost of a national labeling policy?

Labeling of genetically modified food products first became an issue for consumers in the U.S. with the introduction of rBST into the milk supply in 1994. A number of states, including Wisconsin and Vermont, passed laws allowing processors to label their milk as being rBST-free.[1] As the first widely consumed food product produced with GM technology, rBST has garnered a lot of interest in its adoption process, e.g., see Foltz and Chang, Barham et al., but relatively little research has been done on the consumer side. In addition to labels specifically on rBST-free milk, there is an increasingly large market for organic milk and, unlike rBST-free milk, organic labeling standards are determined at the federal level by USDA. Since organic labeled foods are free of GM ingredients and also have other potentially desirable attributes such as being pesticide and antibiotic free, the differences between rBST-free milk and organic milk can identify some of the different values consumers place on product attributes.

Since the possibility of genetically modified foods entering the market became apparent in the early 1990's, a large literature has developed investigating consumer valuations for non-genetically modified foods as well as labels about genetic

[1] Milk that comes from cows treated with rBST is not genetically modified it is the hormone somatotropin that has been genetically engineered. No studies have shown milk from cows treated with rBST to have somatotropin in it that is recognizable as being genetically engineered. However, most labeling of rBST-free milk implies that such would be the case.

modifications, e.g., see Armand-Balmat; Teisel, Bockstael, and Levy;, and Huffman et al. This literature has been based primarily on consumer willingness to pay surveys, by telephone or mail, and experiments conducted with potential consumers of products. Both of these techniques rely on the accuracy of consumers either reached by telephone at home or invited to an artificial laboratory setting to predict their behavior when faced with different products in the supermarket. In addition, due mostly to cost and logistics, many of these are cross sectional, i.e., for a given location and time. In contrast to these studies we use panel data with variation in both location and time.

The present article uses revealed preferences of consumers to study consumer valuations of and associated benefits from rBST-free and organic milk, basing its analysis on scanner data of fluid milk purchases in 12 key US metropolitan markets from Information Resources Inc. (IRI).[2] Of the 12 cities, 4 are in the West census region, 4 in the South census region, 3 in the Midwest, and 1 in the Northeast region. Due to disclosure agreements with IRI we cannot mention the cities or brands included in our analysis. Instead these cities are identified by US census regions as: West census region cities (WT_1,.., WT_4); South census region cities (SO_1,.., SO_4); Midwest region cities (MW_1,.., MW_3); and Northeast region city (NE_1). The database provides detailed brand level information on volume sold, total revenue generated, number of units sold, and the extent of merchandising and price reduction. This data allows a simultaneous exploration of consumer willingness to pay, market structure, and the conduct of firms in these markets. As a result we are able to provide a comprehensive analysis of the U.S. retail fluid milk market by types, i.e., organic, rBST and unlabeled milk.

The use of revealed preference data has a number of obvious advantages over the previous survey and experimental based literature. First and foremost it relies on consumer's actual behavior rather than their behavior in experimental or survey settings. Second data are available for 12 major metropolitan cities spanning U.S. regions and the different types of cities: old industrial city, mainstream fast-growing city, counterculture fast-growing city, etc. Thus one can make some reasonable inferences about the population as a whole from these data. A third advantage is we observe consumer

[2] A Chicago based marketing research firm specializing in archiving and analyzing store and household level scanner data.

responses both at the time they are introduced to a product and their subsequent purchase pattern once they are used to the product in the market. Having this time series avoids potential biases inherent in the experimental and survey literature when consumers are faced with a product they have never seen or tasted before. A final advantage is that rBST-free, organic, and unlabeled milk are all real products that consumers consider buying each time they go to the grocery store.

The goal of this article is to empirically analyze the introduction of GM-free and organic products in the milk market. We do so by estimating price premiums and market shares of different milk types in each of the 12 markets and estimating the benefits to consumers from improved choice sets, e.g., from having only unlabeled milk to having three types of milk, using highly flexible quadratic almost ideal demand system (Q-AIDS) framework as in Banks, Blundell and Lewbel. We use full information maximum likelihood estimation techniques to estimate the demand systems for four regionally and geographically representative markets after controlling for price and expenditure endogeneity as in Dhar, Chavas and Gould. Then we estimate the impact of labeled milk on the competitive structure of the fluid milk market. Based on the estimates we extrapolate to the impacts of newly labeled milk on U.S. fluid milk markets.

The article is organized as follows. First, we describe the data and present descriptive analysis of the products: rBST-free, organic and unlabeled milk and the 12 markets. The reduced form analysis of this section provides insights and guidelines for the structural demand analysis in the section that follows. Second we provide a detailed demand system specification and our estimation methods to generate consistent parameter estimates. Third, we present our empirical specification of the demand, price and expenditure systems. Econometric results and post estimation measures such as price and expenditure elasticities, and welfare impacts of different types of milk are then presented. Finally, a conclusion drawing policy implications for USDA labeling and regulation policy follows.

Data and Descriptive Statistics:

We use retail scanner data from IRI to conduct exploratory market analyses and estimate our demand system. Our scanner database, which was collected so as to be representative of the markets in our 12 cities, provides brand level weekly milk price and sales data starting from 3/9/1997 to the week ending 2/24/2002. Brands that are labeled as rBST-free or organic were identified through interviews with processors and retailers. We augment this database with milk price data from the Federal Milk Marketing Order (FMMO) and a national organic milk producer. The demographic variables come from the U.S. Census. The descriptive statistics of the variables used in our analysis are summarized below.

The simplest method for understanding premiums for rBST-free and organic milk is an investigation of retail price differentials. Tables 1 and 2 present the average prices for the three milk types in our study by city of sale and by year, respectively. On average, price differences between organic and unlabeled milk are about $3.00 per gallon and between rBST-free and unlabeled about $2.00 per gallon. This represents more than a 100% mark-up for organic milk and more than 66% for rBST-free milk. A number of significant differences between milk types and cities, however, become immediately apparent. A western city, WT_4, has the lowest prices for both organic and rBST-free milk, although its price for unlabeled milk is above average. In one of the southern cities, SO_3, and a Midwestern city, MW_2, rBST-free milk is priced at about the same high level as organic milk.

Over the 5 years from 1997 to 2002, prices increased by 24% in organic, 25% in rBST-free, and 13% in unlabeled milk. This asymmetric pattern of price inflation pushed the price differential between organic and unlabeled from $2.68 to $3.64 per gallon (123% of the unlabeled price) and between rBST-free and unlabeled from $1.42 to $2.10 per gallon (70% of the unlabeled price).

Such price differentials show significant willingness-to-pay among certain consumers for the attributes of organic and rBST-free milk. In particular since organic milk represents rBST-free milk with added attributes, e.g., no antibiotics, organic feed given to the cows, and potentially the idea of small-farm production, one can roughly approximate the value to consumers of these different components. Thus, on average over this period, avoiding milk from cows treated with a genetically modified hormone was worth $2.00 per gallon, while drinking milk from cows which also received no antibiotics, were fed organic feeds with no-pesticides, and are advertised as coming from small dairy farms was worth an additional $1.00 per gallon. These averages, however, represent premiums for consumers who bought these types of milk paid but do not identify either the effect of competition between unlabeled and newly labeled milk or the effects on consumers from having broader choice sets of labeled milk. These issues are analyzed in the next section.

Tables 1 and 2 also show market shares by type of milk by city and by year. While unlabeled milk clearly has nearly all of the market share, ranging from a low of 96% in WT_4 to a high of 99.86% in WT_3, rBST-free and organic milks are making in-roads exponentially. There is great variability by city, for example in WT_4 1% of the dollar sales of milk are organic and 2.7% are rBST-free, while MW_3 has no rBST-free sales and a paltry quarter of a percentage of its milk sales being organic.

The yearly share data in table 1 identify two key features: the organic market is growing rapidly, while the rBST-free market seems to have peaked in 1998 and is in decline. Organic market shares increased nearly sevenfold over the same period. The spectacular growth rate in organic market shares does show signs of slowing since it was 94% between 1997 and 1998 had slowed to 16% between 2001 and 2002. Even so, in the end organic still accounts for less than 1% of the milk market.

In contrast, rBST-free milk has a declining market share, suggesting two possible scenarios. It may be that as consumers learn more about rBST over time their perceptions of the risks associated with the technology go down reducing their desire to buy rBST-free milk. Some studies, e.g., Tegene et al., have suggested that information plays a major role in consumer willingness to pay for goods without GM ingredients. Another possibility comes from the literature on product differentiation.[3] From the consumer's perspective these milk products may be vertically differentiated such that given the same price organic milk is preferred to rBST-free milk and rBST-free milk is preferred to unlabeled milk. In this case rBST-free milk might be a "starter" or "gateway" milk for those who would like to buy organic but cannot afford it. Or, a third related possibility is that consumers move up the "quality ladder" from unlabeled to rBST-free to organic in an incremental process driven by learning about the products. In such a scenario rBST-free consumers move to organic because the learning that takes place in purchasing rBST-free milk and reading the labels at the breakfast table makes consumers more likely to purchase organic milk. All of these conjectures would require further study, probably using individual household level data.

To complete the description of the data we present Engel curves for the three types of milk in figures 1, 2, and 3. These curves show per capita dollar expenditures of each milk type as a function of per capita expenditure on all milk.[4] The Engel curves were estimated non-parametrically using the Lowess smoothing technique in order to allow for non-linearities in the curves. The curves show significant differences as well as major non-linear portions, although in the case of unlabeled milk the curve is linear. Organic milk has a convex Engel curve with consumption rising with per-capita milk expenditures. The rBST-free Engel curves, in contrast, are concave suggesting that with higher per capita expenditure consumers tend to consume less of rBST-free milk. The non-linearities of the Engel curves suggest we need to use a rank 3 demand specification as in Banks, Blundell and Lewbell.

A Consumer Demand System for Multiple Milk Types

In this section we describe our choice of demand system and then derive the analytical form of the post estimation measures: elasticities and welfare effects. We specify the demand system at the level of weekly milk purchases in each of the study cities over the study period. Since we are constrained by the available data, this method implicitly assumes a multi-stage household budgeting process in which milk expenditures are weakly separable from other purchases. We believe this is a reasonable assumption given that milk is a necessity and there exists no close substitute for fluid milk.[5] In estimating disaggregate demand systems such an assumption of weak separability is a necessity at some level, since it is almost impossible to estimate a full demand system that includes all products with disaggregated product level data. For example, even studies in the literature that test for weak separabilty implicitly assume that weak separabilty holds at some stage of the consumer budgeting process, e.g., see Eales and Unnevehr; Nayga and Capps. Thus, like the rest of the demand system literature, we are

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[3] For detailed discussion on the concept of product differentiation see Tirole.

[4] Drawing Engel curves with respect to expenditures provides information on how purchases of different types of milk change with respect to overall milk expenditures. These expenditure Engel curves are different than Engel curves drawn with respect to total income.

[5] For detailed discussion on weak separability and estimation of disaggregated product or brand level demand systems please refer to Dhar, Chavas, and Gould. They reject weak separability in the context of carbonated beverages but they find that controlling for the endogeneity of prices and expenditures as done in this application affects the test for weak separability such that null hypothesis of weak separabilty can in some cases be accepted.

constrained by the completeness of disaggregated data necessary to make interesting inferences at the product level and need to assume weak separability at the level of milk versus all other household purchases.

Quadratic Almost Ideal Demand System

To specify demand for different types of milk we use the Q-AIDS demand system. Our non-parametric analysis of Engel curves suggests that the relationship between per capita expenditure on any milk type and total per capita expenditure on milk is non-linear. Banks, Blundell and Lewbel have shown that in the presence of such non-linear Engel curves use of a rank 2 demand system such as the standard AIDS model is inappropriate. The Q-AIDS is the best available exactly aggregable demand system to capture any non-linear impacts of price and expenditure changes on demand. The demand system underlying the Q-AIDS is of rank 3, which, as proved in Gorman, is the maximum possible rank for any demand system that is linear in functions of income. Unlike the AIDS model (Deaton and Muelbauer, 1980a,b) and the exactly aggregable Translog model of Jorgenson, Lau, and Stoker, the Q-AIDS model permits goods to be luxuries at some income level and necessities at others.

In order to derive a Q-AIDS demand system let $e(p, u)$ be the household expenditure function, where $p \in R^n_{++}$ is the $(n\times 1)$ price vector of the $(n\times 1)$ vector of consumption goods $q \in R^n_+$. Under the almost ideal class of demand systems,

$\ln e(p,u) = \ln a(p) + c(p)\left[d(p) + u^{-1}\right]^{-1}$, where:

$\ln a(p) = \alpha_0 + \alpha^T \ln p + 0.5(\ln p)^T \Gamma(\ln p)$, $c(p) = \beta^T \ln p$, and $d(p) = \tau^T \ln p$.

Denoting by k_n the $(n\times 1)$ vector $\begin{bmatrix} \mathrm{k} \\ \vdots \\ \mathrm{k} \end{bmatrix}$, the parameters $(\alpha, \beta, \tau, \Gamma)$ satisfy the restrictions:

$\alpha^T 1_n = 1$, $\beta^T 1_n = 0$, $\tau^T 1_n = 0$, $\Gamma\, 1_n = 0_n$ (homogeneity/adding up), and $\Gamma^T = \Gamma$ (symmetry). Letting $x > 0$ be household expenditure, the Marshallian demand specification (with $q_1,\ldots,q_n$ *quantity demanded)* in terms of expenditures shares $w \equiv (p_1 q_1^*/x, \ldots, p_n q_n^*/x)^T$ are

(1) $\quad w = \alpha + \Gamma \ln p + \beta [\ln x - \ln a(p)] + \tau [\ln x - \ln a(p)]^2/c(p)$.

In order to facilitate the empirical implementation one can also specify this demand specification in summation notation as:

$$(2) \qquad w_{ilt} = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln(p_{jlt}) + \beta_i \ln\left({x_{lt}}/{P_{lt}} \right) + \frac{\tau_i}{\prod_{i=1}^{N} p_{ilt}^{\beta_i}} \left[\ln\left({x_{lt}}/{P_{lt}} \right) \right]^2,$$

where $p = (p_1, \ldots, p_N)'$ is a $(N\times 1)$ vector of prices for q, and $w_{ilt} = (p_{ilt}\, q_{ilt}/x_{lt})$ is the budget share for the i^{th} commodity consumed in the l^{th} city at time t. The term P_{lt} , the price index can be expressed as:

$$ln(P_{lt}) = \delta + \sum_{m=1}^{N} \alpha_m\, ln(p_{mlt}) + 0.5 \sum_{m=1}^{N} \sum_{j=1}^{N} \gamma_{mj}\, ln(p_{mlt})\, ln(p_{jlt}).$$

The above Q-AIDS specification (equation 2) can be modified to incorporate the effects of socio-demographic variables ($Z_{1lt}, \ldots, Z_{Klt}$) on consumption behavior, where Z_{klt} is the k^{th} socio-demographic variable in the l^{th} city at time t, $k = 1, \ldots, K$. This method, demographic translating, allows demographic differences to shift both the intercept and elasticity parameters. Under demographic translating, α_i is assumed to take the following form: $\alpha_{ilt} = \alpha_{0i} + \sum_{k=1}^{K} \lambda_{ik} Z_{klt}$, $i = 1, \ldots, N$.

Q-AIDS and Substitution Between Milk Types

From estimating a Q-AIDS model, one can recover detailed compensated and un-compensated own and cross price elasticities, expenditure elasticities, and measures of consumer welfare. The own and cross price elasticities allow us to analyze the substitution behavior of consumers between the different types of milk as a way of describing consumer demand for labeled milk. Together these elasticities describe the patterns of consumer willingness to pay for labeled milk.

Differentiating the demand system (equation 1) with respect to ln$p$ and ln$x$ and aggregating over city (l) and time (t), gives us price and expenditure elasticity measures.

Let $\mu_i = \dfrac{\partial w_i}{\partial \ln x} = \beta_i + \dfrac{2\lambda_i}{b(P)} \left\{ \ln\left[\dfrac{x}{a(P)} \right] \right\}$ and

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i \left(\alpha_j + \sum_k \gamma_{jk} \ln p_k \right) - \frac{\lambda_i \beta_j}{b(p)} \left\{ \ln\left[\frac{x}{a(p)} \right] \right\}^2.$$ Then the expenditure

elasticities are given by: $e_i = \frac{\mu_i}{w_i} + 1$. The uncompensated price elasticities are given by $e_{ij}^u = \frac{\mu_{ij}}{w_i} - \delta_{ij}$ where δ_{ij} is the Kronecker delta. We use the Slutsky equation to calculate the set of compensated elasticities such that: $e_{ij}^C = e_{ij}^u + e_i w_j$.

Q-AIDS and Measurement of the Benefits from Labeled Milk

Since rBST-free and organic milks were just being introduced to the general milk market during this period, one can think of measuring consumer valuation of labeled milk as measuring the benefits of a new product introduction. New products have two effects: on the one hand they raise competition, potentially lowering prices of all related goods; on the other they provide increased choice to consumers which according to standard consumer theory should have a non-negative effect on consumer utility. Since we observe markets both with and without each of the labeled milk varieties we can use this variation in the data along with the Q-AIDS model to identify key components of consumer benefits from the product.

The standard approach in the literature on product introductions, e.g., see Hausman; and Hausman and Leonard, measures the total effect on consumers from the introduction of new products as the difference in the consumers' expenditure function before and after the introduction, i.e., the compensating variation, *CV*. Holding utility constant at the post-introduction level, compensating variation can be described as:

(3) $$CV = e(p_1, p_N, r, u_1) - e(p_1, p_N^*(p_0), r, u_1),$$

where p_1 is the vector of post-introduction prices of the competing products, p_N is the post-introduction price of the new product(s), p_0 is the pre introduction prices, r is a price vector for products outside the industry, and u_1 is the post-introduction utility level. The function $p_N^*(p)$ defines the 'virtual' price for the new products, which is the reservation price at which demand for the new product would be zero given the prices of the other products.

This total benefit to consumers can be decomposed into two components:

(4a) $$CV = \left(\left[e(p_1, p_N, r, u_1) - e(p_1, p_N^*(p_1), r, u_1)\right] + \left[e(p_1, p_N^*(p_1), r, u_1) - e(p_1, p_N^*(p_0), r, u_1)\right]\right),$$

which can be re-written as:

(4b) $CV = -(VE + CE)$.

Here the first term (*VE*) represents a variety effect, implying the change in consumer welfare due to the availability of the new products(s), holding the prices of the existing brands constant at the pre-introduction level. The second term is the competitive effect (*CE*), which represents the consumer welfare due to the change in the prices of existing brands after the introduction. The impact of the competitive effect can be positive or negative based on the nature of competition between firms producing the products originally on the market and those that have entered the market.

The variety effect can be estimated indirectly out of the parameters of the Q-AIDS demand system as the area under the estimated demand curve between actual price/consumption points and the price that sets consumption equal to zero. The competitive effect can be estimated directly from the milk price series before and after introduction of a labeled milk variety.[6] The empirical techniques for estimating these effects are described below.

Estimation Procedures for the Demand System

A number of previous studies have found problems of endogeneity of price and expenditure in estimating demand systems using aggregate scanner data such as those used in this article, e.g., see Dhar, Chavas and Gould. In order to account for potential price and expenditure endogeneity, our estimation procedure for the Q-AIDS demand system, equation (2), includes an additional set of equations that simultaneously estimate the determinants of milk prices and milk expenditures as functions of exogenous variables. We estimate our demand equations, reduced form price equations, and expenditure equation using a full information maximum likelihood (FIML) estimation method.[7] Due to adding up restrictions of the Q-AIDS demand system we drop one demand equation and estimate a system with 2 demand equations, 3 reduced form price equations, and 1 expenditure equation.

[6] Note that it is also possible to generate indirect estimates of the competitive effect from the Q-AIDS system if one is willing to assume that the milk processors are engaged in a Bertrand competition game. Since part of the purpose of this paper is to evaluate whether or not there is any competition between labeled and unlabeled milk it would be counter productive to assume a specific type of competition.

[7] An alternative is the GMM framework developed by Banks, Blundell, and Lewbell.

The reduced form price equations used to control for price endogeneity for each milk type (unlabeled, rBST-free, and organic) are specified to capture the supply side of the price formation mechanism. The price equation for the i^{th} commodity in the l^{th} city at time t is:

(5) $$p_{ilt} = f(supply/demand\ shifters).$$

In equation (5) supply/demand shifters would include variables to describe raw material, product manufacturing, and packaging costs. Following Blundell and Robin we specify a reduced form expenditure equation where household expenditure in the l^{th} city at time t is a function of median household income and a time trend:

(6) $$M_{lt} = f(time\ trend,\ income).$$

Given these reduced form specifications for the price and expenditure equations, we estimate jointly (2), (5) and (6) by FIML. The resulting parameter estimates have desirable asymptotic properties (Amemiya).

To control for city specific variations, we modify the Q-AIDS specification with demographic translating variables ($Z_{1lt}, \ldots, Z_{Klt}$). Our AIDS model also incorporates a set of four seasonal dummy variables for each city along with socio-demographic variables. In order to maintain theoretical consistency of the AIDS model, the following restrictions are applied to the demographic translating parameter α_{0i}:

(7) $$\alpha_{0i} = \sum_{r=1}^{4} d_{ir} D_r\ ,\ \sum_{r=1}^{4} d_{ir} = 1,\ i = 1, \ldots, N,$$

where d_{ir} is the parameter for the i^{th} brand associated with the seasonal dummy variable D_r for the r^{th} season. Note that as a result, our demand equations do not have intercept terms.

Empirical Specifications

Price Specification

Most recent studies of differentiated products have modeled price as a function of supply and demand shifters, assuming these shifters are exogenous to the price formation mechanism, e.g., Cotterill, Franklin and Ma; Cotterill, Putsis and Dhar; and Kadiyali, Vilcassim and Chintagunta. For milk products, raw milk prices account for 62% of the retail milk price and thus can be used as a reasonable proxy for a large part of the variability in manufacturing costs (U.S. G.A.O.). Other important retailing and processing costs we include in the price formation equation provide proxies for labor, merchandising, and packaging costs. We therefore specify the retail price functions, equation (5), with raw milk price, marketing and other product characteristics as explanatory variables:

$$(8)\quad \begin{aligned} \ln(p_{ilt}) &= \theta_{i0} + \theta_{i1}\ln(C\_p_{ilt}) + \theta_{i2}\left[\ln(C\_p_{ilt})\right]^2 + \theta_{i3}\ln(wage_{lt}) \\ &+ \theta_{i4}\ln(p_{ilt-1}) + \theta_{i5}PRD_{ilt} + \theta_{i6}UPV_{ilt}\ , \end{aligned}$$

where p_{ilt} is the retail price of milk type *i*, in city *l* and at time *t*. As a measure of milk costs, C_p_{lt} is the price of announced cooperative class 1 milk price in city *l* at time *t*. Similarly, $wage_{lt}$ is the wage rate in city *l* at time *t* and p_{ilt-1} is the lagged retail price. As a measure of the average size of purchases UPV_{ilt} is the unit volume of the i^{th} product in the l^{th} city at time *t*. For example, if a consumer purchases only one gallon bottles of a brand, then unit volume for that brand will be just one. Conversely, if this consumer buys a half-gallon bottle then the unit volume will be 2. This variable is used to capture packaging-related cost variations, as smaller package size per volume implies higher costs to produce, distribute, and shelve. The variable PRD_{ilt} is the percent price reduction of brand *i* and is used to capture any costs associated with specific price reductions such as aisle end displays or freestanding newspaper inserts.

Expenditure Specification

Similarly the reduced form expenditure function in (6) is specified as:

$$(9)\qquad \ln(x_{lt}) = \psi_0 + \psi_1 TR_t + \psi_2\ln(x_{lt-1}) + \psi_3\ln(wage_{lt}) + \psi_4 C\_idx_{lt}\ ,$$

where $t = 1,\ldots, 260$ and ψ_0 is the intercept term. TR_t is a linear trend, capturing any unobservable time specific effects on consumer milk expenditures. The variable $wage_{lt}$ is the average wage rate in city *l* and is used as a proxy to capture the effect of income differences on milk purchases. x_{lt-1} is lagged expenditure by one period. C_idx_{lt} is the city level consumer price index; this variable captures any city level overall supply shocks to consumers.

In general the reduced form specifications, equations (8) and (9), are always identified, although the issue of parameter identification is rather complex in such non-linear structural models.[8] We checked the order conditions for identification that would

[8] For a detailed discussion please refer to Mittelhammer, Judge and Miller (pp.474-475).

apply to a linearized version of the demand equations (2) and found them to be satisfied. Finally, we did not uncover numerical difficulties in implementing the FIML estimation. As pointed out by Mittelhammer, Judge and Miller we interpret this as evidence that each of the demand equations is identified.[9]

Translating

Our translating specification (e.g. $\alpha_{ilt} = \alpha_{0i} + \sum_{k=1}^{K} \lambda_{ik} Z_{klt}$) has four quarterly dummies and two continuous variables. These two variables are: the monthly wage rate in the city and the consumer price index. The seasonal dummies capture any seasonal variations in a given city. The wage rate variable captures any impact of changes in income on milk consumption. And lastly the consumer price index captures any exogenous shocks in other markets on the consumption of milk.

Q-AIDS Model Estimation Results

Table 3 provides parameter estimates for the demand system, reduced form price and expenditure equations. In total we estimate 45 parameters, 34 of them are significant at a 5% level of significance. Both of our estimated β parameters measuring how consumption of milk changes with expenditure are significant at a 5% level of significance. Of the two estimated τ parameters, which describe the quadratic term on expenditure, one of them is significant at the 5% level and the other one is significant the 10% level. The significance of parameters (τ) associated with the quadratic part of the demand system validates the choice of a Q-AIDS formulation for demand. A likelihood ratio also rejects the null hypothesis that AIDS and Q-AIDS models are equal at the 1% level of significance ($\chi^2(2) = 16.94$).

Analysis of Elasticity Estimates:

Table 4 presents expenditure elasticity estimates and associated standard errors while tables 5(a) and 5(b) present uncompensated and compensated price elasticity estimates and associated standard errors. We estimate elasticities at the mean of the variables and find all of them to be significantly different from zero at a 5% level or less. The un-

[9] Due to space limitations, we report only related econometric results. More complete results are available

compensated price elasticities are not significantly different from the compensated ones. Since this implies that the overall impact of per capita expenditure on milk consumption is minimal, the analysis of price elasticities uses un-compensated price elasticities.

All types of milk show, as expected, negative uncompensated own-price elasticities. Of the own price effects rBST-free milk has the highest own price elasticities (-4.40) followed by organic milk (-1.37) and unlabeled milk has the lowest (-1.04). rBST-free and organic milk have negative cross price elastiticities, implying they are complements to each other. In contrast the positive cross price elasticities between unlabeled and both rBST-free and organic milks implies that unlabeled milk is a substitute for both of them. This substitution pattern is, however, asymmetric suggesting greater movement to organic and rBST-free milk than back to unlabeled milk. For example, a 1% change in the price of unlabeled milk leads to a large switch from unlabeled to other milk: a 1.51% change in rBST-free milk demand and a 3.15% change in organic milk demand. On the other hand, a 1% price change in rBST-free milk leads to only a 0.05% change in unlabeled demand, and 1% price change in organic milk leads to only a 0.02% change in demand for unlabeled milk. This implies that once consumers switch to higher priced products, i.e. rBST-free and organic, they usually do not switch back to unlabeled milk even for significant price changes. Such stickiness in consumer behavior may suggest that once consumers choose labeled milk they perceive a quality difference in comparison to unlabeled milk as would be the case in a vertically differentiated product market.[10] Consumers in vertically differentiated markets do not tend to switch back to a lower quality product once they switch to a higher quality product.[11]

Among the expenditure elasticities, rBST-free milk has the highest (4.39) and organic milk has the lowest (0.5) elasticity. Unlabeled milk has, as expected, an expenditure elasticity just below unity suggesting a necessity. The low expenditure elasticity for organic milk is perhaps surprising given that the organic milk is commonly perceived to be associated with higher income groups of the population. But the

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from the authors on request.

[10] Interestingly, blind taste tests conducted informally by the authors could discern no quality differences in terms of taste between these three types of milk.

[11] A classic example of a vertically differentiated market is the computer chip market. Once consumers switch to Pentium 4 chips they prefer not to switch back to Pentium 3 or lower quality chips.

relationship between income and milk expenditure may not be positively correlated. It is commonly known that large families with children tend to have higher per capita expenditure on milk. In that case our result suggests that smaller families with no children would tend to consume more organic milk. In the case of rBST-free milk early work on rBST in milk by Grobe and Douthitt does suggest that risk perceptions of rBST are negatively correlated with income, which would be consistent with these results. Similar to the arguments made in the case of organic milk, it is probable that large families with children are interested in minimizing the risks associated with artificial hormones but not that interested in other associated benefits of organic milk. Another possible explanation is that we are only estimating a partial demand system and we have not fully accounted for cross expenditure effects. Estimates that test household and income effects as well as this article's assumption of weak separability would best be done with household level data, which presents an important avenue for future research.

Estimating Consumer Benefits

As demonstrated above, consumer willingness to pay for labeled milks can be estimated by the compensating variation. This compensating variation has two elements a competitive effect and a variety effect. The estimation procedure and results for each of these elements are described below.

Competitive Effects:

The strategy for identifying the competitive effects of specialty milks is to compare prices in markets and times in which they are sold with those where and when they are not offered for sale. The data set includes one city where no rBST-free milk was sold, 6 cities that experienced an introduction of organic milk, and 7 cities that experienced an rBST-free milk introduction. This provides a way to value consumer surplus from rBST-free and organic milk by observing the effects of their introduction on prices of unlabeled milk, which is the competition effect (CE). If the introduction of these specialty milks reduces the price of unlabeled milk, then consumers benefit from the competition even if they do not purchase the specialty milk. This competition effect would be over and above the benefit, utility, gained by those who consume specialty milk described by the variety effect.

Following Hausman and Leonard let the pricing equation for unlabeled (non-specialty) milk be described in the following manner:

(10) $$p_{it} = W_t + I_{it}\delta_1 + B_{it}\delta_2 + \varepsilon_{it}$$

$$where \;\; \varepsilon_{it} = \nu_i + \mu_{it} .$$

The dependent variable is the price of milk in city *i* during week *t*. The time specific effects in the market are captured by the 0-1 indicator variables for each of 260 weeks, W_t. In order to account for fixed effects in each market, the error structure is assumed to include a city specific effect v_i and a mean zero error term μ_{it}. The indicators I_{it} capture the effects of an introduction of specialty milks, equaling 1 if it is present in the market and zero otherwise. Thus, the coefficient δ_1 represents the competitive effect (CE), the change in price with the introduction of labeled milk having controlled for city and time specific effects. The variable B_{it} represents the number of brands in a city during a particular week in order to control for the general effects of brand introduction in the estimation.

The equation is estimated using weekly prices per gallon averaged across brands of unlabeled milk in each of 12 cities as the dependent variable. Results for the key parameters of interest are presented in table 6. The estimated competition effect is strong with milk prices shown to be decreasing in the total number of brands, as well as the introduction of organic and rBST-free brands. More importantly, the introduction of organic milk or rBST-free milk has an effect of decreasing the price 6 or 7 times lower than the entry of another unlabeled milk brand. This price reduction due to the competitive effect of organic and rBST-free milk together reduce the price almost 2 cents per gallon. While 2 cents represents less than 1% of the average price paid, when these numbers are aggregated to a national figure they imply a net competitive effect of specialty milk of about \$2.5 million per week or \$130 million per year. This represents the benefit consumers of unlabeled milk receive from the existence of labeled/specialty milk in the market, even though they do not purchase it.

Variety effect:

As mentioned above we use our demand system parameter estimates to measure variety effects for the introduction of rBST-free and organic milk. Table 7 presents estimates of the virtual prices, which are the prices at which quantity purchased would be driven to zero, and the variety effects consumers receive from having rBST-free and organic labeled milk in the market. We estimate the virtual price of a milk type by solving our estimated Q-AIDS setting the budget share of the milk type to zero.

The virtual prices show some important differences between how rBST-free milk and organic milk are priced in the market. RBST-free milk has a much lower virtual price and is priced in most markets within $1.50 of its virtual price. This implies that rBST-free brands have relatively little pricing power and that raising rBST-free milk to the price of organic would result in near zero sales. On the other hand the lower estimated price elasticities for organic milk imply much higher virtual prices and significant scope for price increases in the absence of competition. These differences also suggest that most of the consumer benefits from labeled milk come from organic milk rather than from rBST-free milk.

From the virtual prices and the estimated demand surface curvatures one can calculate the variety effect, which, averaged across the four cities, is 17 cents per capita per gallon per week. This implies a representative consumer across these four cities receives 17 cents worth of benefit per week just from the option of having rBST-free and organic milk in his/her choice set. There are, however, significant variations at the city level. The highest per capita variety effect is in a western city, WT_4, (27 cents per week), and the lowest is in a southern city, SO_1, (12 cents per week). The ranking of these benefits between these cities does not match with the ranking of median household income of the cities, suggesting the common perception that organic and rBST-free milk consumption is positively associated with income may need to be investigated further in the future.

Based on an estimated per capita yearly benefit of $8.84 per person the total variety effect benefit to all 26 million consumers in the four cities combined is $234 million per year. When aggregated to the national level, the variety effect equals $2.5 billion per year in consumer benefits from having rBST-free and organic milk in the market. If the average benefit to any U.S. consumer is equal to the estimated lowest benefit for any given city (i.e., SO_1) then the benefit would equal to $1.7 billion. The variety effect dwarfs the estimated competitive effect and is more than five times the estimated expenditure of U.S. consumers on organic milk.

Conclusions and Policy Implications

Labeling of products provides important information for consumers both about the contents and taste of the product as well as the process by which they are produced. In many products, labels generate trust, brand loyalty, and allow increased pricing power by the sellers. The labels in this article fall into the category of being process labels, although in some cases consumers may infer content and taste attributes to those labels. As process labels, they most closely resemble labels such as "dolphin-free tuna" which make claims about the process but not directly about the quality of the contents. In addition these are voluntary labels in that no company selling rBST-free or organic milk is obliged to advertise the process under which their milk is produced. At a minimum, the mere persistence of the labels in the market suggests a non-zero willingness to pay for the production characteristics of rBST-free and organic milk. And our results also suggest that consumers on average are willing to pay significant premiums for such process labeling.

Specifically in this article we investigated consumer benefits from the introduction of rBST-free and organic milk using retail price differentials and a quadratic version of the almost ideal demand system in a revealed preference analysis. In contrast to most of the literature on valuing GM-free goods, these estimates take into account changes in consumer behavior over time and the price effects of competition between processors. This work finds consumers pay significantly more for rBST-free and organic milk but also derive significantly large benefits from having them both in the market. The results show that nationally, consumers benefit both from the competition induced by labeled milk and by the benefits of an increased choice set. In addition, this work has identified much greater consumer benefits to organic milk than rBST-free milk, which is like organic but may come from cows treated with antibiotics and that eat feed from fields potentially treated with herbicides and pesticides.

These results shed some light on USDA labeling policy options for organic and GM-free goods. It seems clear that consumers derive significant benefits from being able to buy organic milk and rBST-free milk and to the extent a national organic standard is necessary the benefits are quite large. One should note that a less stringent standard would have very little benefit to consumers. This presents a cautionary tale to policy makers considering creating organic standards with low thresholds: these efforts to create weak labels may not be worth the consumer benefits.

A number of productive avenues for future research remain for investigation. The surprising result that higher per capita expenditure is not associated with higher organic milk purchases deserves particular attention. It is possible that organic purchases are being driven by ideology or risk preferences as much as income and future research might benefit from controlling for those effects. Finally it is clear that the market for labeled milk has significant scope for non-competitive behaviors which is a direction we plan to investigate in the future.

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Table 1. Average Milk Price and Market Share by City

	Price			Market Share		
City Code	Organic	rBST Free	Unlabeled	Organic	rBST Free	Unlabeled
MW_1	6.44	5.32	2.82	0.37	0.41	99.21
MW_2	6.23	6.15	2.51	0.23	0.0005	99.77
MW_3	5.86	.	2.68	0.25	-	99.75
NE_1	5.57	4.28	2.80	0.87	0.18	98.94
SO_1	5.93	4.92	3.06	0.23	0.41	99.35
SO_2	6.43	5.92	3.02	0.09	0.004	99.91
SO_3	5.74	6.01	2.44	0.43	0.29	99.27
SO_4	5.70	5.30	3.16	0.29	0.19	99.52
WT_1	6.02	4.56	3.10	0.86	1.13	98.01
WT_2	5.98	4.22	2.58	0.13	0.002	99.87
WT_3	5.85	4.80	2.38	0.08	0.005	99.91
WT_4	5.28	3.69	3.01	1.10	2.69	96.21
Average	5.91	4.85	2.80	0.41	0.48	99.14

Table 2. Average Milk Price and Market Share by Year

	Price			Market Share		
Year	Organic	rBST Free	Unlabeled	Organic	rBST Free	Unlabeled
1997	5.26	3.97	2.57	0.12	0.30	99.60
1998	5.50	4.38	2.69	0.23	0.61	99.21
1999	5.72	4.76	2.84	0.36	0.56	99.12
2000	6.06	4.97	2.85	0.54	0.50	98.998
2001	6.55	5.53	2.97	0.69	0.42	98.92
2002	6.82	5.81	2.95	0.80	0.45	98.79

Table 3. Demand System Regression Results

Variables	Estimates	t-stat	Variables	Estimates	t-stat
Q-AIDS Parameters			**Price Equations**		
Quarterly Binary 1 in rBST Milk	0.17	4.39	Intercept: rBST Milk	-0.25	-3.90
Quarterly Binary 2 in rBST Milk	0.17	4.41	Intercept: Organic Milk	-0.21	-3.40
Quarterly Binary 3 in rBST Milk	0.18	4.43	Intercept: Unlabeled Milk	-0.48	-4.94
Quarterly Binary 4 in rBST Milk	0.17	4.40	Coop Milk Price: rBST-free milk	0.04	0.67
Quarterly Binary 1 in Organic Milk	0.00	-0.46	Coop Milk Price: Organic milk	0.12	1.79
Quarterly Binary 2 in Organic Milk	-0.02	-1.62	Coop Milk Price: Unlabeled milk	-0.06	-0.98
Quarterly Binary 3 in Organic Milk	-0.26	-18.29	Wage Rate: rBST-free Milk	0.12	6.84
Quarterly Binary 4 in Organic Milk	-0.26	-18.35	Wage Rate: Organic Milk	0.03	3.43
Wage in rBST Milk	-0.26	-18.33	Wage Rate: Unlabeled Milk	0.14	7.44
CPI in rBST Milk	-0.26	-18.28	Lagged Price: rBST-free Milk	0.74	39.75
Wage in Organic Milk	-0.02	-12.49	Lagged Price: Organic Milk	0.88	72.38
CPI in Organic Milk	0.07	19.88	Lagged Price: Unlabeled Milk	0.83	44.38
β in rBST Milk	0.07	4.02	% Price Reduction: rBST-free milk	-0.01	-6.65
β in Organic Milk	-0.02	-3.90	% Price Reduction: Organic milk	-0.01	-8.97
τ in rBST Milk	0.02	1.95	% Price Reduction: Unlabeled milk	-0.01	-9.92
τ in Organic Milk	-0.01	-3.35	Unit per volume: rBST-free milk	0.05	9.71
Γ_{11}	-0.03	-9.50	Unit per volume: Organic milk	0.12	4.43
Γ_{12}	-0.02	-13.33	Unit per volume: Unlabeled milk	0.08	3.32
Γ_{22}	0.00	-1.66	Coop Milk Price^2: rBST-free milk	0.06	0.77
Expenditure Function			Coop Milk Price^2: Organic milk	-0.07	-1.44
Intercept	-0.28	-1.08	Coop Milk Price^2: Unlabeled milk	0.08	0.92
Time trend	0.01	10.18			
Lagged expenditure	0.75	37.23			
wage rate	0.28	9.46			
CPI	-0.18	-3.12			

Table 4: Expenditure Elasticities

Products	Estimates
rBST Free	4.39
	(14.19)
Organic	0.50
	(5.01)
Unlabeled	0.97
	(266.65)

T-statistics are in parentheses below the estimates.

Table 5a: Price Elasticities (Un-Compensated)

Products	rBST Free	Organic	Unlabeled
rBST Free	-4.40	-1.66	1.51
	(-12.81)	(-12.88)	(2.76)
Organic	-2.51	-1.37	3.15
	(-9.97)	(-6.36)	(12.36)
Unlabeled	0.05	0.02	-1.04
	(12.66)	(12.61)	(-152.93)

T-statistics are in parentheses below the estimates.

Table 5b: Price Elasticities (Compensated)*

Products	rBST Free	Organic	Unlabeled
rBST Free	-4.40	-1.66	1.55
	(-12.80)	(-12.88)	(2.84)
Organic	-2.51	-1.37	3.15
	(-9.97)	(-6.36)	(12.37)
Unlabeled	0.05	0.02	-1.08
	(12.54)	(12.44)	(-226.29)

T-statistics are in parentheses below the estimates.

Table 6: Reduced Form Price Model - Fixed Effects

Dependent variable: Price of unlabeled milk	Estimates	t-stat
Organic brand introduction	-0.01	-4.65
rBST-free brand introduction	-0.01	-5.62
Total number of brands in market	-0.0012	-8.49
Constant	0.36	48.03

N=3120, Number of cities=12;

R-square: within = 0.457; between = 0.097; overall = 0.104

Note: Equation includes 259 weekly dummy variables.

Table 7: Virtual Price and Variety Effects

City	Indirect Utility	rBST Free Prices		Organic Prices		Variety Effect	City Population	Total Benefit from Variety Effect
		Virtual	*Mean*	*Virtual*	*Mean*			
SO_1	0.417	5.78	4.92	35.09	5.93	0.12	3,433,400	405,230
	(0.000)	(0.001)		(0.003)		(0.001)		
NE_1	0.332	4.45	4.28	89.34	5.57	0.16	5,091,700	824,409
	(0.000)	(0.001)		(0.005)		(0.001)		
WT_1	0.410	5.85	4.56	55.70	6.02	0.13	15,116,700	2,040,496
	(0.000)	(0.001)		(0.004)		(0.001)		
WT_4	0.505	7.56	3.69	382.62	5.28	0.27	2,846,800	781,881
	(0.000)	(0.003)		(0.007)		(0.003)		
All Four Cities	0.417	5.82	4.36	93.97	5.70	0.17	26,488,600	4,544,434
	(0.000)	(0.001)		(0.005)		(0.001)		

Notes: Total Benefit is estimated on a per week basis. Virtual prices estimated from Q-AIDS model, mean prices are the average market price. Numbers in parentheses are standard errors or estimates.

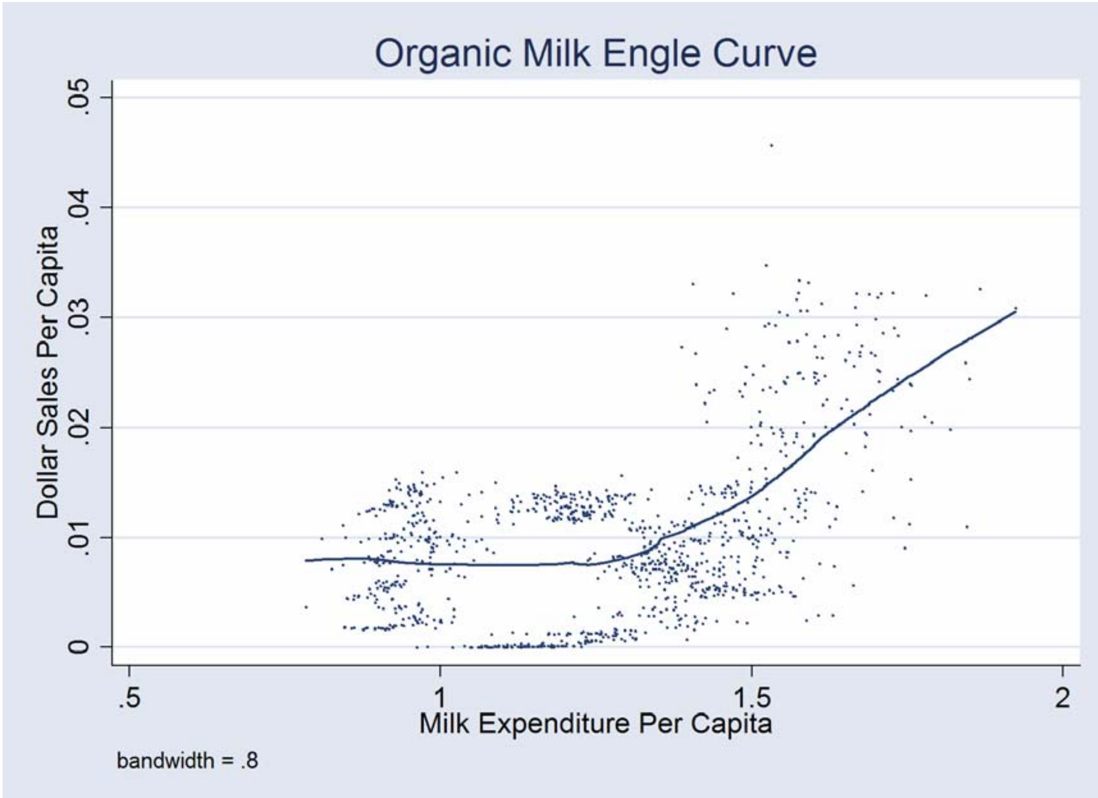

Figure 1. Non-parametric Engel curve: organic milk

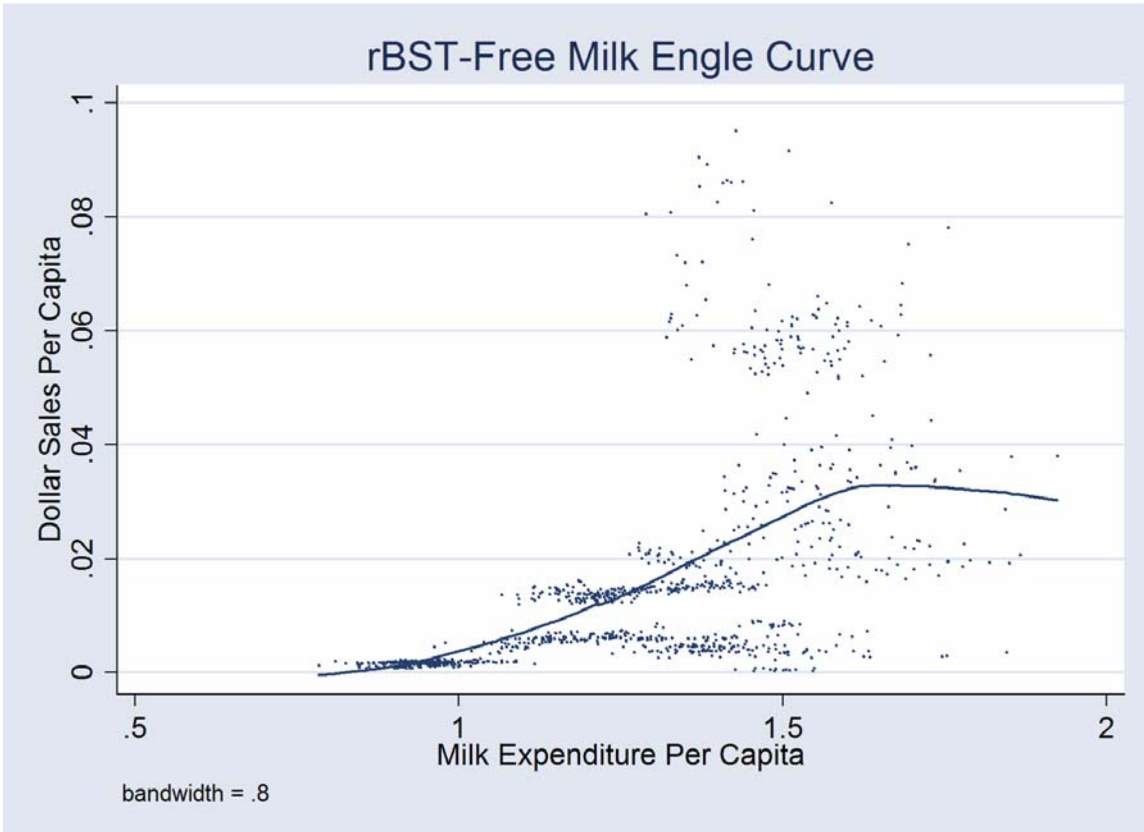

Figure 2. Non-parametric Engel curve: rBST-free milk

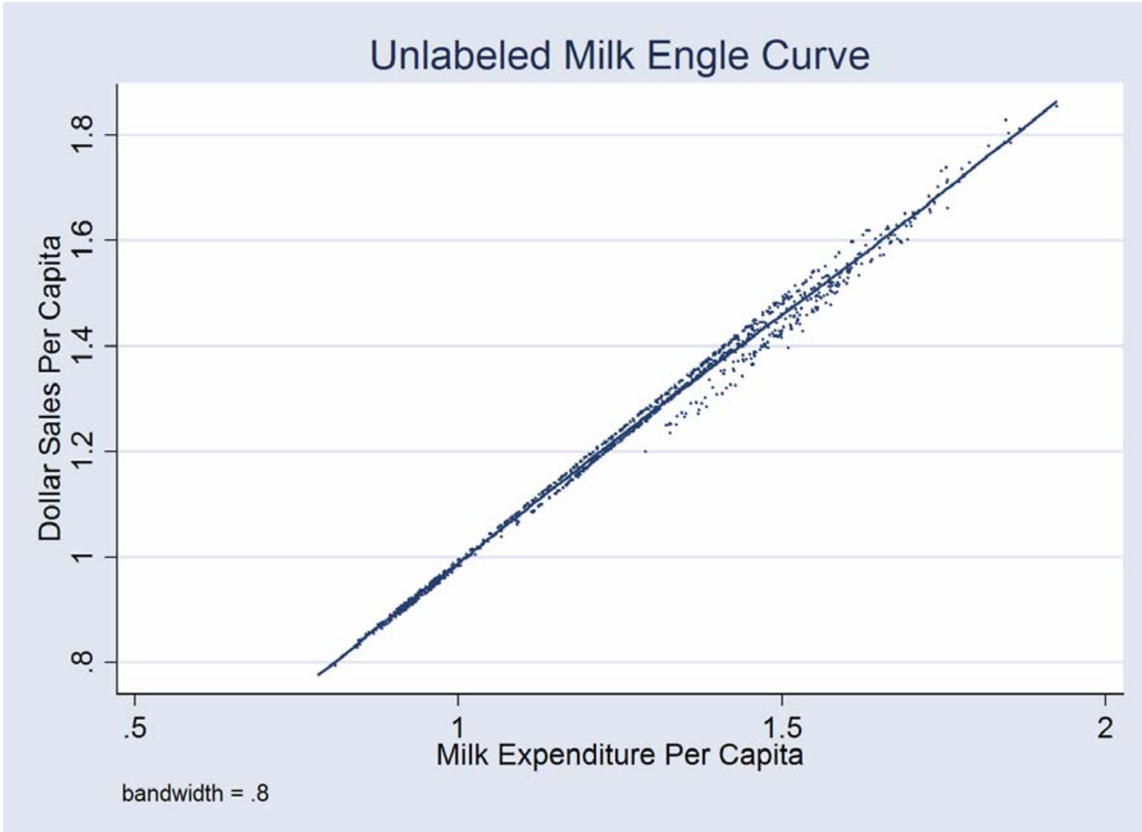

Figure 3. Non-parametric Engel curve: Unlabeled milk