Modeling the U.S. Dairy Sector with Government Intervention

Donald J. Liu, Harry M. Kaiser, Timothy D. Mount, and Olan D. Forker

An econometric framework for estimating a two-regime dairy structural system is presented. Failure to account for switching between regimes due to government price intervention raises the problem of selectivity bias. Further, since a structural system of equations is involved, the problem is not limited to the market associated with the intervention. Rather, bias from a single source can distort all equations in the system. The ramifications of not correcting for the bias in policy analyses are investigated.

Key words: dairy, price intervention, switching simultaneous system, Tobit estimation.

The federal dairy price support program was enacted in 1949 as a means of improving farm prices and incomes. Under this program, the government attempts to support raw milk prices by buying an unlimited quantity of manufactured dairy products at the wholesale level whenever the market price falls below the announced government purchase price. The intervention of the government in this market has broad-reaching effects not only on the farm level but also on the wholesale and retail levels. Our objectives are to: (*a*) investigate the implications of this type of intervention on the econometric specification of a structural model of the U.S. dairy industry and (*b*) examine the empirical ramifications of not using the appropriate specification in policy analyses.

When considering how prices in the dairy sector are determined, the potential for government intervention introduces a special problem. Prices are determined by different forces depending upon whether the price established by competitive supply and demand conditions is above or below the government price floor. If the competitively determined market price for wholesale manufactured dairy products is above the government purchase price, a "market equilibrium" regime holds. In this case, the observed wholesale manufactured price is the equilibrium price and hence government intervention does not influence the price formation process in the dairy sector. On the other hand, if the competitively determined market price is below the purchase price, then a "government support" regime holds. In this case, the observed wholesale manufactured price equals the government price and the government buys the excess supply at that level. Hence, government intervention influences the type of price formation process that operates in the market as well as the level of prices.

Is the U.S. dairy sector really characterized by a mixture of the two regimes? Due to recent large annual government purchases, it is tempting to describe the dairy sector exclusively as a government support regime. However, this observation is not appropriate when examining the market on a quarterly or monthly basis, particularly prior to the 1980s. More importantly, using government purchases (rather than the relationship between the government price and the market price) for regime identification is flawed for the dairy sector. Some specialized manufacturing plants package products according to government standards and are not equipped to sell in commercial markets even when the competitive price exceeds the government price. Using the price relationship as a criterion to identify regime, the results in figure 1 show that the com-

Donald J. Liu is an assistant professor in the Department of Economics at Iowa State University. Harry M. Kaiser is an associate professor, Timothy D. Mount and Olan D. Forker are professors in the Department of Agricultural Economics at Cornell University.

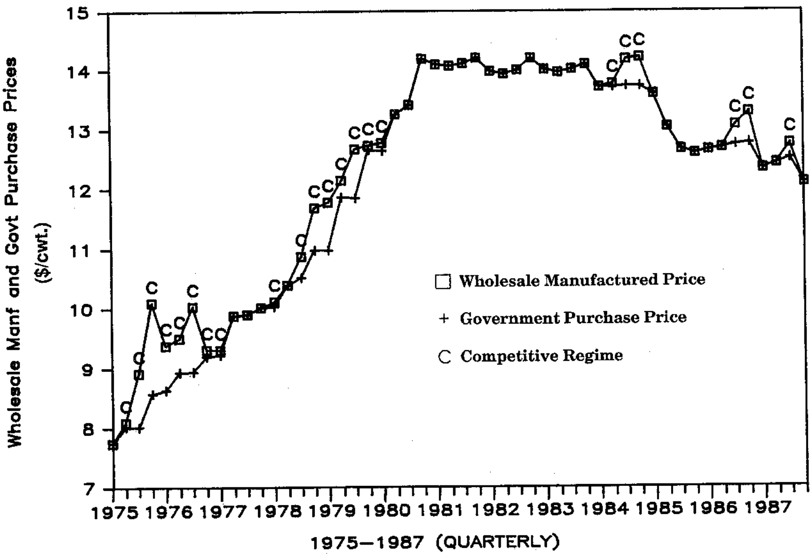


Figure 1. Relationship between the wholesale manufactured and government purchase price, 1975–87

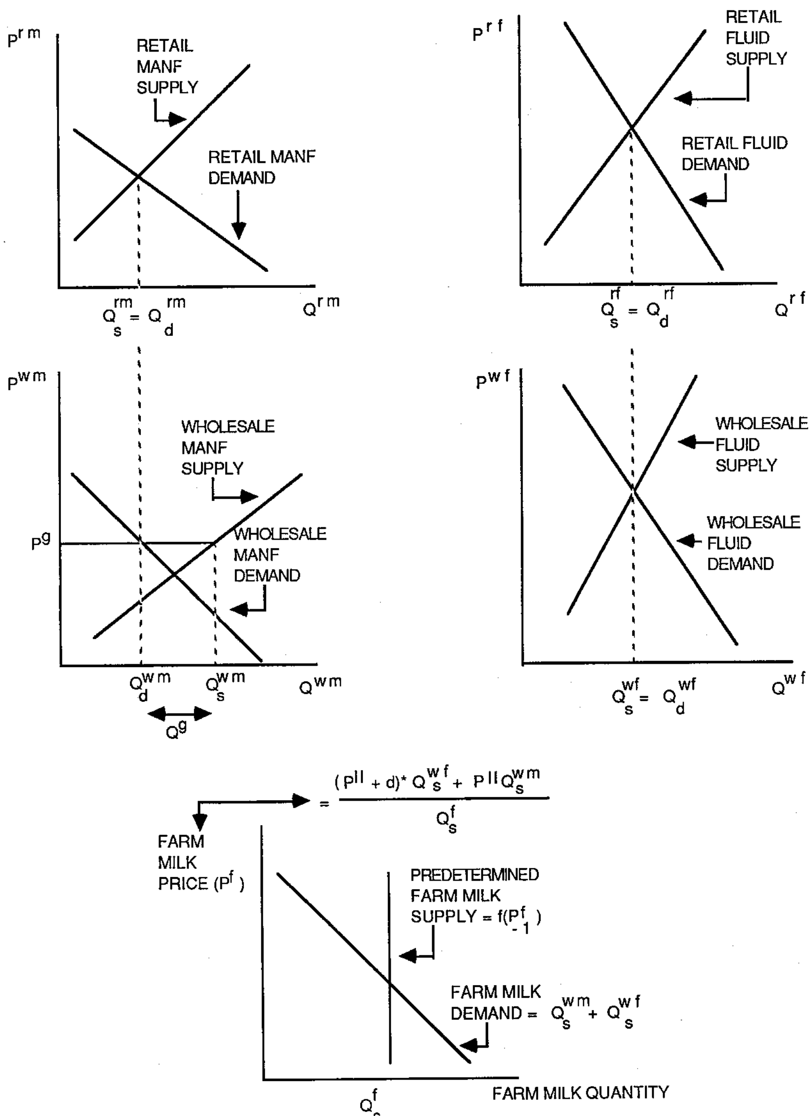
petitive regime held for 42% of the period 1975–87. Even during the 1980s when dairy surpluses were relatively large, the competitive regime occurred in 22% of that sample. Hence, with data from 1975 through 1987, it appears that the two-regime system should be considered when specifying a model of the dairy sector.

To date, econometric studies of the dairy sector have not distinguished between the two regimes and have instead assumed that the government regime always occurs (Kaiser, Streeter, and Liu; LaFrance and de Gorter; Liu and Forker). This is due to the fact that these studies have not included a wholesale manufactured dairy market where government intervention occurs. Failure to account for switching between regimes raises the problem of selectivity bias, implying that conventional least squares estimates may be biased and inconsistent. Furthermore, since a structural system of equations is involved, these problems are not limited to the market associated with the intervention. Bias from a single source can distort all equations in the system. The issue here is to determine whether these distortions are important for policy analysis.

In the following sections, an econometric framework for estimating a two-regime dairy structural system is presented. Correcting for selectivity bias implies modifying the first stage of a conventional two-stage least squares estimator and providing an alternative set of instruments for the second stage. Since the conventional two-stage least squares model is not nested in the bias-corrected model, Atkinson's test for nonnested models is used to determine which one is supported best by the data. It is shown that the bias-corrected model is supported in all equations, but the conventional model is rejected in four out of five equations. Finally, the ramifications of using the conventional rather than the bias-corrected model in policy analyses are investigated by shocking policy variables in both models. The resulting impacts on key endogenous variables are found to be significantly different between the two models.

A Conceptual Framework

The econometric model of the dairy industry consists of farm, wholesale, and retail levels. At the farm level, raw milk is produced and sold to wholesalers, who in turn process and sell it to retailers. Both wholesale and retail levels are divided into a manufactured and a fluid market. The construction is similar to a previous model by Kaiser, Streeter, and Liu in that milk products are divided into fluid and manufactured dairy products. However, the previous model only considered the retail and the farm levels. The extension to include



*To simplify, this figure ignores changes in commercial inventories, specialized plant quantity, and farm use.

Figure 2. Conceptual model of the U.S. dairy market

a wholesale level in this study facilitates the incorporation of government intervention in the wholesale manufactured market. A schematic view of the various components of the dairy sector is presented in figure 2.

Government intervention occurs in the wholesale manufactured market for cheese, butter, and nonfat dry milk. Figure 2 illustrates the occurrence of a government support regime, where the market equilibrium wholesale manufactured price is below the government support price (P^g). In this case, Q_d^{wm} is demanded in the commercial market, which is less than what is supplied (Q_s^{wm}), and the government purchases the excess supply (Q^g). In the case of the market equilibrium regime (not shown), the market equilibrium price is at or above P^g, wholesale manufactured supply equals demand, and Q^g equals zero.

In the retail manufactured market, a general specification for supply, demand, and the equilibrium condition can be written as:[1]

$$\text{(1a)}\quad \ln Q_s^{rm} = \alpha_s^{rm}\ln P^{rm} + \beta_s^{rm}\ln P^{wm} + \gamma_s^{rm}\ln Z_s^{rm} + \mu_s^{rm},$$

$$\text{(1b)}\quad \ln Q_d^{rm} = \beta_d^{rm}\ln P^{rm} + \gamma_d^{rm}\ln Z_d^{rm} + \mu_d^{rm}, \quad \text{and}$$

$$\text{(1c)}\quad \ln Q_s^{rm} = \ln Q_d^{rm} \equiv \ln Q^{rm},$$

where Q_s^{rm} and Q_d^{rm} are the retail manufactured quantity supplied and demanded, P^{rm} and P^{wm} are the equilibrium retail manufactured price and wholesale manufactured price, Z_s^{rm} and Z_d^{rm} are vectors of exogenous supply and demand shifters pertaining to the retail manufactured market, Q^{rm} denotes the equilibrium retail manufactured quantity, and ln is the natural logarithm. The αs, βs, and γs are the coefficients, and μ_s and μ_d are error terms.

The retail fluid supply, demand, and equilibrium condition can be written following the form of the retail manufactured market as follows:

$$\text{(2a)}\quad \ln Q_s^{rf} = \alpha_s^{rf}\ln P^{rf} + \beta_s^{rf}\ln P^{wf} + \gamma_s^{rf}\ln Z_s^{rf} + \mu_s^{rf},$$

$$\text{(2b)}\quad \ln Q_d^{rf} = \beta_d^{rf}\ln P^{rf} + \gamma_d^{rf}\ln Z_d^{rf} + \mu_d^{rf}, \quad \text{and}$$

$$\text{(2c)}\quad \ln Q_s^{rf} = \ln Q_d^{rf} \equiv \ln Q^{rf},$$

where superscripts *rf* and *wf* represent the retail and wholesale fluid markets, respectively.

The wholesale manufactured supply, demand, and equilibrium condition (without government purchases) are:

$$\text{(3a)}\quad \ln Q_s^{wm} = \alpha_s^{wm}\ln P^{wm} + \beta_s^{wm}\ln P^{\mathrm{II}} + \gamma_s^{wm}\ln Z_s^{wm} + \mu_s^{wm},$$

$$\text{(3b)}\quad \ln Q_d^{wm} = \ln Q^{rm}, \quad \text{and}$$

$$\text{(3c)}\quad \ln Q_s^{wm} = \ln(Q_d^{wm} + QSP + \Delta INV),$$

where P^{II} is the Class II price, QSP is the quantity of milk sold to the government by specialized plants, ΔINV is change in commercial inventories of manufactured products, and all other variables are similarly defined with superscript *wm* denoting variables pertaining to the wholesale manufactured market. Equation (3b) specifies that the wholesale manufactured demand should equal the equilibrium retail manufactured quantity as all the quantity variables are expressed on a milk-equivalent basis. Finally, the variables QSP and ΔINV are treated as exogenous in this study because they comprise a very small and rather constant portion of manufactured quantity.[2]

The wholesale fluid supply, demand, and equilibrium condition can be written following the form of the wholesale manufactured market as follows:

$$\text{(4a)}\quad \ln Q_s^{wf} = \alpha_s^{wf}\ln P^{wf} + \beta_s^{wf}\ln(P^{\mathrm{II}} + d) + \gamma_s^{wf}\ln Z_s^{wf} + \mu_s^{wf},$$

$$\text{(4b)}\quad \ln Q_d^{wf} = \ln Q^{rf}, \quad \text{and}$$

$$\text{(4c)}\quad \ln Q_s^{wf} = \ln Q_d^{wf},$$

where d is the exogenous Class I differential. All other variables are defined as above with superscript *wf* denoting that the variables pertain to the wholesale fluid subsector.

The wholesale manufactured price appearing in (1a) and (3a) is constrained by the dairy price support program. That is, since the government sets a purchase price for storable manufactured dairy products and is willing to buy surplus quantities of the products at that price, the following constraint holds:

$$\text{(5)}\quad \ln P^{wm} \geq \ln P^{g},$$

where P^g is the aggregate government purchase price for the manufactured products at the wholesale level.

When the government support regime holds, P^{wm} simply equals P^g which is exogenous. However, the quantity of government purchases emerges as an additional endogenous variable balancing the number of equations with the number of unknowns. Accordingly, the equilibrium condition of (3c) for the wholesale manufactured market becomes:

$$\text{(3c}')\quad \ln Q_s^{wm} = \ln(Q_d^{wm} + QSP + \Delta INV + Q^g),$$

where Q^g is government purchases measured on a milk-equivalent basis.

[1] In the model that follows, we present a log-linear specification because the empirical counterpart uses this specification. If a linear model is desired, simply replace the logarithm measurement by its level for all variables.

[2] While small does not by itself guarantee exogeneity (Binkley), the first differences of these variables appear to be stationary with a strong seasonal pattern. Hence, they are treated as being exogenous.

Given the retail and the wholesale equations in (1)–(5), the dairy model can be completed by introducing the farm market. To simplify, it is assumed that dairy farmers' price expectations are based solely on lagged prices. Accordingly, the farm supply equation is specified as:

(6a) $\ln Q_s^f = \alpha_s^f \ln L(P^f) + \gamma_s^f \ln L(Z_s^f) + \mu_s^f,$

where Q_s^f is the farm milk supply, P^f is the farm milk price, the f superscript represents the farm market, and L is the lag operator with $L(X) \equiv X_{-1}$. Since milk used for fluid and manufactured purposes commands different prices, the farm milk price is related to the average of the Class I and Class II prices via the following equation:

(6b) $$P^f = \frac{(P^{\text{II}} + d)*Q_s^{wf} + P^{\text{II}}*Q_s^{wm}}{(Q_s^f - FUSE)},$$

where $FUSE$ is on-farm use of milk, which is assumed to be exogenous. Finally, the farm-level equilibrium condition is:

(6c) $\ln Q_s^f = \ln(Q_s^{wf} + Q_s^{wm} + FUSE).$

To summarize, because of the naive farm price expectation assumption, the farm milk supply is predetermined at each point in time.[3] Hence, the above dairy model is recursive in nature consisting of a retail-wholesale subsystem [equations (1)–(5)] and a farm market [equations (6a–c)]. The focus of this study is to examine the appropriate estimation procedure for the retail-wholesale subsystem, given the recursive structure of the dairy model.[4] The retail-wholesale subsystem encompasses two possible regimes. In the case of the market equilibrium regime, the endogenous variables are: retail manufactured demand and supply and wholesale manufactured demand ($Q_d^{rm} = Q_s^{rm} = Q_d^{wm}$), wholesale manufactured supply (Q_s^{wm}), retail and wholesale fluid supply and demand ($Q_s^{rf} = Q_d^{rf} = Q_s^{wf} = Q_d^{wf}$), retail manufactured price (P^{rm}), wholesale manufactured price (P^{wm}), retail fluid price (P^{rf}), wholesale fluid price (P^{wf}), and Class II price (P^{II}). The exogenous variables, denoted by Z, are:

$$Z = (Z_s^{rm}, Z_d^{rm}, Z_s^{rf}, Z_d^{rf}, Z_s^{wm}, Z_s^{wf}, Q_s^f, d, FUSE, QSP, \Delta INV).$$

In the case of the government support regime, Q^g replaces P^{wm} as an endogenous variable in this list, and the exogenous variables, denoted by Z_*, are

$$Z_* = (Z, P^g).$$

The Switching System Estimation Procedure

Taking the unconditional expectation of the structural equations (1a), (1b), (2a), (2b), (3a), and (4a) yields:

(7a) $E[\ln Q_s^{rm}] = \alpha_s^{rm} E[\ln P^{rm}] + \beta_s^{rm} E[\ln P^{wm}] + \gamma_s^{rm} \ln Z_s^{rm},$

(7b) $E[\ln Q_d^{rm}] = \beta_d^{rm} E[\ln P^{rm}] + \gamma_d^{rm} \ln Z_d^{rm},$

(7c) $E[\ln Q_s^{rf}] = \alpha_s^{rf} E[\ln P^{rf}] + \beta_s^{rf} E[\ln P^{wf}] + \gamma_s^{rf} \ln Z_s^{rf},$

(7d) $E[\ln Q_d^{rf}] = \beta_d^{rf} E[\ln P^{rf}] + \gamma_d^{rf} \ln Z_d^{rf},$

(7e) $E[\ln Q_s^{wm}] = \alpha_s^{wm} E[\ln P^{wm}] + \beta_s^{wm} E[\ln P^{\text{II}}] + \gamma_s^{wm} \ln Z_s^{wm},$ and

(7f) $E[\ln Q_s^{wf}] = \alpha_s^{wf} E[\ln P^{wf}] + \beta_s^{wf} E[\ln(P^{\text{II}} + d)] + \gamma_s^{wf} \ln Z_s^{wf}.$

The estimation procedure is analogous to conventional two-stage least squares, consisting of the following two steps. The first step is to estimate the expected prices in the right-hand side of (7a)–(7f) to be used as instrumental variables for prices in the structural equations estimation of the second step. Once the instrumental variables for price (hereafter referred to as price instruments) are obtained, the second step involves a straightforward application of ordinary least squares to the structural equations (1a), (1b), (2a), (2b), (3a), and (4a) with the price instruments replacing the

[3] Previous studies in farm milk supply have found that using lagged prices as proxies for price expectations fits the data well (e.g., Chavas and Klemme; Kaiser, Streeter, and Liu; and Liu and Forker). On the other hand, LaFrance and de Gorter employed the current price of milk in the supply equation and used instrumental variable methods to deal with simultaneous determination of supply and demand. To assess the appropriateness of the predetermined farm milk supply in our quarterly model, the Hausman endogeneity test was conducted. The hypothesis that the farm milk supply was not predetermined was rejected at the 5% significance level. Specifically, if Q_s^f is predetermined, the reduced form for the farm milk price in (6b) can be estimated as a function of all exogenous variables in the system, including Q_s^f. On the other hand, if Q_s^f is not predetermined, it has to be replaced by an appropriate instrument [say, $L(Q_s^f)$] in the above regression. If the assumption that Q_s^f is predetermined is correct, then the difference in the coefficients from the two reduced-form estimations should be close to zero.

[4] The farm market equation was estimated in Liu et al. (1990) and the whole dairy model was used to conduct policy simulations involving various generic dairy advertising scenarios.

observed prices. The task is to obtain a consistent estimate of the reduced-form price instruments.

Since the underlying market structures are different between regimes, there are two sets of reduced-form equations with different endogenous variables (P^{wm} or Q^{g}) and different sets of exogenous variables (Z or Z_*). In the market equilibrium regime, the reduced-form equations for the prices are:

(8a) $\ln P^{wm} = \pi^{wm} \ln Z + \epsilon^{wm} > \ln P^{g}$ and

(8b′) $\ln P^{i} = \pi^{i}_{*} \ln Z_{*} + \epsilon^{i}_{*} \quad i = rm, rf, wf,$ II,

In the government support regime, the reduced-form equations are:

(8a′) $\ln P^{wm} = \ln P^{g}$ and

(8b′) $\ln P^{i} = \pi^{i}_{*} \ln Z_{*} + \epsilon^{i}_{*} \quad i = rm, rf, wf,$ II,

where equations (8b) and (8b′) pertain to retail manufactured price, retail fluid price, wholesale fluid price, and Class II price. It is important to note that the structural error terms, μs, enter the log-linear price reduced-form equations in an additive fashion. Hence, the price reduced-form error terms will be normally distributed if the structural error terms are normally distributed. Since normality of ϵs is important to the procedure that follows, we demonstrate the connection using a simple two-market model in the appendix.

Define the probability that the government support solution occurs as Φ and the probability that the market equilibrium solution occurs as $1 - \Phi$. That is,

$$\Phi \equiv \text{PROB}\{\ln P^{wm} \leq \ln P^{g}\} \quad \text{and}$$
$$1 - \Phi \equiv \text{PROB}\{\ln P^{wm} > \ln P^{g}\}.$$

Consider first the reduced-form equation for the wholesale manufactured price in (8a) and (8a′). Since this price is constrained to not be less than the government purchase price, the use of ordinary least squares to estimate (8a) results in selectivity bias. Combining the two reduced-form equations in (8a) and (8a′) for the two solution regimes weighted by their respective probabilities and taking the unconditional expectation of the resulting expression yields:

(9) $E[\ln P^{wm}] = (1 - \Phi)E[\ln P^{wm} \mid \ln P^{wm} > \ln P^{g}] + \Phi \ln P^{g}.$

Assuming that ϵ^{wm} is normally distributed, $E[\ln P^{wm} \mid \ln P^{wm} > \ln P^{g}]$ can be expressed as (Maddala, pp. 158–59):

(10) $E[\ln P^{wm} \mid \ln P^{wm} > \ln P^{g}] = \pi^{wm} \ln Z + \sigma\{\phi(c)/[1 - \Phi(c)]\},$

where $\Phi(c)$ and $\phi(c)$ are, respectively, the cumulative standard normal and the standard normal density, both evaluated at c which is defined as $(\ln P^{g} - \pi^{wm} \ln Z)/\sigma$, and σ^2 is $\text{Var}[\epsilon^{wm}]$. The coefficients for π^{wm} and σ, as well as for ϕ and Φ in (10), can be estimated simultaneously and consistently by applying a maximum likelihood Tobit procedure on (8a). The last term in (10) is the Heckman correction term for selectivity bias (Heckman). Then, by substituting (10) into (9), the price instrument for the wholesale manufactured price is:

(11) $E[\ln P^{wm}] = (1 - \Phi)\pi^{wm} \ln Z + \Phi \ln P^{g} + \sigma\phi.$

Now consider the reduced-form equations for the unconstrained prices (i.e., retain manufactured price, retail fluid price, wholesale fluid price, and Class II price) in (8b) and (8b′). Combining the two reduced-form equations for the two solution regimes weighted by their respective probabilities and taking the unconditional expectation of the resulting expression yields:

(12) $E[\ln P^{i}] \equiv (1 - \Phi)\{\pi^{i} \ln Z + E[\epsilon^{i} \mid \ln P^{wm} > \ln P^{g}]\} + \Phi\{\pi^{i}_{*} \ln Z_{*} + E[\epsilon^{i}_{*} \mid \ln P^{wm} \leq \ln P^{g}]\}.$

Assuming the joint density of ϵ^{wm} and ϵ^{i} is bivariate normal and making use of (8a), the following holds:[5]

(13)
$$E[\epsilon^{i} \mid \ln P^{wm} > \ln P^{g}] = E[\epsilon^{i} \mid \epsilon^{wm} > \ln P^{g} - \pi^{wm} \ln Z] = (\sigma^{i}/\sigma)\{\phi(c)/[1 - \Phi(c)]\},$$

where σ^{i} is $\text{COV}[\epsilon^{wm}\epsilon^{i}]$.

Similarly, assuming the joint density of ϵ^{wm} and ϵ^{i}_{*} is bivariate normal and making use of (8a), the following holds:

[5] Assuming that the joint density of x and y is bivariate normal with zero means, Johnson and Kotz show that

$$E[x \mid y > z] = \{\text{COV}[x, y]/\text{SD}[y]\} \cdot \{\phi(\xi)/(1 - \Phi(\xi))\}, \quad \text{and}$$
$$E[x \mid y < z] = -\{\text{COV}[x, y]/\text{SD}[y]\}\{\phi(\xi)/\Phi(\xi)\},$$

where COV and SD are the covariance and standard deviation operators and ξ is defined as $z/\text{SD}[y]$.

(14)
$$E[\epsilon_*^i | \ln P^{wm} \le \ln P^g] = E[\epsilon_*^i | \epsilon^{wm} \le \ln P^g - \pi^{wm} \ln Z] = -(\sigma_*^i/\sigma)\{\phi(c)/\Phi(c)\},$$

where σ_*^i is $\mathrm{COV}[\epsilon^{wm}\epsilon_*^i]$. The price instrument for the unconstrained prices may be obtained by substituting (13) and (14) into (12) to give:

(15)
$$E[\ln P^i] = \pi^i[(1 - \Phi)\ln Z] + \pi_*^i [\Phi \ln Z_*] + (\sigma^i - \sigma_*^i)[\phi/\sigma].$$

With estimates of Φ, ϕ, and σ from the Tobit estimation in (10), the parameters π^i, π_*^i, and $(\sigma^i - \sigma_*^i)$ in (15) can be estimated by ordinary least squares with the observed values of $\ln P^i$ replacing $E[\ln P^i]$. The last term in (15) resembles the Heckman correction term in (10).

To summarize, rather than regressing each endogenous variable on all exogenous variables to obtain the price instrument, the reduced-form equation for the wholesale manufactured price should be estimated by a Tobit procedure while those for other endogenous prices should be fitted to a weighted average of the exogenous variables from each regime with a Heckman-like correction term appended.

Tests Against the Conventional Model

To investigate whether the above bias-corrected procedure matters empirically, the following tests can be applied to the reduced-form equations. With respect to the wholesale manufactured price reduced-form equation in (10), the second term on the right-hand side is the Heckman correction term for selectivity bias. Hence, a t-test for the estimate of σ can be used to determine the existence of the bias if ordinary least squares is used instead of the Tobit procedure.

With respect to the remaining four unconstrained price reduced-form equations in (15), a procedure based on the Atkinson nonnested models test is used to compare models (Atkinson; Judge et al., p. 438). Specifically, there are two nonnested models that need to be compared, the bias-corrected model represented by (15) and the conventional two-stage least squares reduced-form model which is:

(16) $$E[\ln P^i] = \pi_*^i \ln Z_*.$$

Following Atkinson, a comprehensive model composed of both (15) and (16) is constructed to test the two competing models. The comprehensive model is obtained by augmenting the government purchase price ($\ln P^g$) into the exogenous vector Z in the first term of (15):

(17) $$E[\ln P^i] = \pi_a^i[(1 - \Phi)\ln Z_*] + \pi_*^i[\Phi \ln Z_*] + (\sigma^i - \sigma_*^i)[\phi/\sigma],$$

where the augmented parameter vector π_a^i contains π^i and an additional parameter (ξ^i) for the government purchase price.

The bias-corrected model in (15) can be obtained by imposing the following single restriction on the comprehensive model (17):

(18) $$\xi^i = 0.$$

An F-test on (18) can be used to determine the appropriateness of the bias-corrected model. Similarly, an F-test on the following set of restrictions can be used to determine the appropriateness of the conventional model in (16):

(19) $$\pi_a^i - \pi_*^i = 0 \quad \text{and} \quad \sigma^i - \sigma_*^i = 0.$$

The Estimation Results

Based on the conceptual model, there are six structural equations that need to be estimated: retail fluid demand, retail manufactured demand, retail fluid supply, wholesale fluid supply, retail manufactured supply, and wholesale manufactured supply. These equations are estimated simultaneously by the switching regime estimation procedure discussed previously using quarterly data from 1975 through 1987.[6]

[6] The data used to estimate the structural equations come from a variety of sources. Selected years of *Federal Milk Order Market Statistics* [U.S. Department of Agriculture (USDA) 1970–88a] were used for the Class II price, Class I differential, and retail and wholesale fluid demand and supply. Selected issues of *Dairy Situation and Outlook* (USDA 1970–88b) were used for milk production, net government price support program purchases, commercial inventories, and on-farm use of milk. This source also was used to construct the retail manufactured price index, which is a weighted average of retail cheese, butter, and ice cream price indices. It also was used to construct the aggregate government purchase price and wholesale manufactured market price. The *Handbook of Basic Economic Statistics* (Bureau of Economic Statistics) was used for the average hourly wage in manufacturing and civilian population. U.S. Department of Labor (USDL), Bureau of Labor Statistics' publications *Consumer Price Index* (USDL 1970–88a), *Producer Price Index* (USDL 1970–88c), and *Employment and Earnings* (USDL 1970–88b) were used to obtain data on all retail and wholesale prices and on the unemployment rate and disposable income. Finally, *Leading National Advertisers* (Leading National Advertisers, Inc.) was used for generic advertising expenditures for fluid and manufactured products. A detailed description and listing of the data is presented in Liu et al. (1989).

Table 1. Estimated Structural Equations (The Bias-Corrected Model)

Retail Fluid Demand

$$\begin{aligned}\ln(Q_d^{rf}/POP) = {} & \underset{(-14.88)}{-2.236} - \underset{(-2.34)}{.282}\ \ln(P^{rf}/INC) + \underset{(2.31)}{.154}\ \ln(PBEV/INC) + \underset{(2.01)}{.0025}\ \ln DGFA \\ & + \underset{(2.01)}{.004}\ \ln DGFA_{-1} + \underset{(2.01)}{.0045}\ \ln DGFA_{-2} + \underset{(2.01)}{.004}\ \ln DGFA_{-3} + \underset{(2.01)}{.0025}\ \ln DGFA_{-4} \\ & - \underset{(-6.79)}{.179}\ \ln TIME - \underset{(-3.60)}{.028}\ SIN1 + \underset{(10.70)}{.083}\ COS1 + \underset{(3.24)}{.517}\ \mu^{rf}_{d_{-1}}\end{aligned}$$

Adj. $R^2 = .88$ Durbin-Watson = 1.84

Retail Manufactured Demand

$$\begin{aligned}\ln(Q_d^{rm}/POP) = {} & \underset{(-10.42)}{-2.467} - \underset{(-2.68)}{.928}\ \ln(P^{rm}/INC) + \underset{(2.29)}{.645}\ \ln(PMEA/INC) + \underset{(1.64)}{.0009}\ \ln DGMA \\ & + \underset{(1.64)}{.0014}\ \ln DGMA_{-1} + \underset{(1.64)}{.0016}\ \ln DGMA_{-2} + \underset{(1.64)}{.0014}\ \ln DGMA_{-3} + \underset{(1.64)}{.0009}\ \ln DGMA_{-4} \\ & - \underset{(-2.09)}{1.436}\ \ln DPAFH + \underset{(2.64)}{.071}\ \ln TIME - \underset{(-4.92)}{.050}\ SIN1 - \underset{(-8.29)}{.085}\ COS1\end{aligned}$$

Adj. $R^2 = .85$ Durbin-Watson = 2.07

Retail Fluid Supply

$$\begin{aligned}\ln Q_s^{rf} = {} & \underset{(6.00)}{2.809} + \underset{(1.82)}{.940}\ \ln(P^{rf}/P^{wf}) - \underset{(-3.68)}{.111}\ \ln(PFE/P^{wf}) - \underset{(-3.95)}{.015}\ UNEMP \\ & + \underset{(1.76)}{.237}\ \ln Q^{rf}_{s_{-1}} - \underset{(-1.98)}{.227}\ \ln Q^{rf}_{s_{-4}} - \underset{(-1.90)}{.001}\ TIME - \underset{(-3.90)}{.052}\ SIN1 + \underset{(8.14)}{.094}\ COS1\end{aligned}$$

Adj. $R^2 = .90$ Durbin-h = 1.60

Retail Manufactured Supply

$$\begin{aligned}\ln Q_s^{rm} = {} & \underset{(-1.69)}{-1.507} + \underset{(2.37)}{.683}\ \ln(P^{rm}/P^{wm}) - \underset{(-1.51)}{.334}\ \ln(MWAGE/P^{wm}) - \underset{(-2.78)}{.042}\ COS1 \\ & + \underset{(2.21)}{.163}\ \ln Q^{rm}_{s_{-1}} + \underset{(6.55)}{.581}\ \ln Q^{rm}_{s_{-4}}\end{aligned}$$

Adj. $R^2 = .93$ Durbin-h = 1.36

Wholesale Fluid Supply

$$\begin{aligned}\ln Q_s^{wf} = {} & \underset{(4.03)}{2.184} + \underset{(2.66)}{.381}\ \ln(P^{wf}/(P^{II} + d)) - \underset{(-2.85)}{.093}\ \ln(PFE/(P^{II} + d)) - \underset{(-3.98)}{.016}\ UNEMP \\ & + \underset{(1.79)}{.240}\ \ln Q^{wf}_{s_{-1}} - \underset{(-1.96)}{.223}\ \ln Q^{wf}_{s_{-4}} - \underset{(-3.74)}{.003}\ TIME - \underset{(-3.74)}{.050}\ SIN1 \\ & + \underset{(8.18)}{.094}\ COS1\end{aligned}$$

Adj. $R^2 = .90$ Durbin-h = 1.13

Wholesale Manufactured Supply

$$\begin{aligned}\ln Q_s^{wm} = {} & \underset{(2.70)}{.528} + \underset{(1.50)}{.870}\ \ln(P^{wm}/P^{II}) - \underset{(-2.86)}{.544}\ \ln(MWAGE/P^{II}) - \underset{(-4.37)}{.122}\ POLICY \\ & + \underset{(3.40)}{.301}\ \ln Q^{wm}_{s_{-1}} + \underset{(4.15)}{.351}\ \ln Q^{wm}_{s_{-4}} + \underset{(4.29)}{.00017}\ TIME^2 + \underset{(4.08)}{.077}\ SIN1 \\ & - \underset{(-6.42)}{.125}\ COS1 + \underset{(4.05)}{.751}\ \mu^{wm}_{s_{-1}}\end{aligned}$$

Adj. $R^2 = .96$ Durbin-h = .25

The retail fluid and manufactured demand equations are estimated on a per capita basis, while the retail and wholesale supply equations are estimated on a total quantity basis because population is not a supply determinant. Both demand equations are expressed as functions of their own price, per capita income, price of substitutes, advertising, a time trend, harmonic seasonal variables, and other shifters. The supply equations are expressed as functions of their own price, input prices, lagged supply, harmonic seasonal variables, and other shifters. The estimation results are in table 1. All the estimated coefficients have correct signs and are significant at conventional confidence levels (as indicated by the t-values in parentheses). The adjusted R-squared, Durbin-Watson statistics, and Durbin-h statistics suggest good fit of the data. A more specific explanation of the equations follows.

Per capita retail fluid demand (Q_d^{rf}/POP) is estimated as a function of the ratio of the retail fluid milk price index (P^{rf}) to per capita income (INC), the ratio of the retail nonalcoholic beverage price index ($PBEV$) to per capita income, deflated generic fluid advertising expenditures

(*DGFA*), a time trend (*TIME*), and two harmonic seasonal variables (*SIN*1 and *COS*1).[7] The specification of the two price-to-income ratios is consistent with the zero homogeneity assumption for prices and income (Phlips, pp. 37–38). The beverage price index is a proxy for the price of fluid product substitutes. The current and lagged advertising variables account for the impact of advertising on demand.[8] The time trend (first quarter of 1975 equals one) captures the effect of changes in consumer preferences over time, specifically, the increasing concern about the link between heart disease and fluid milk consumption. The two harmonic seasonal variables capture seasonality in demand. Based on the estimated autocorrelation function and partial autocorrelation function of the residuals, a first-order moving-average error structure is imposed. All the coefficients remain stable after imposing the moving-average term.

Per capita retail manufactured demand (Q_d^{rm}/POP) is estimated as a function of the ratio of the retail manufactured price index (P^{rm}) to per capita income, the ratio of the retail meat price index (*PMEA*) to per capita income, deflated generic manufactured advertising expenditures (*DGMA*), the deflated retail price index for food away from home (*DPAFH*), a time trend, and the two harmonic seasonal variables. The meat price index is a proxy for the price of manufactured product substitutes. The away-from-home price index is included because a large portion of cheese is consumed away from home. The trend variable measures the increase in consumer preferences for cheese and yogurt. Unlike fluid products, consumers do not perceive manufactured products such as cheese as high-fat products even though they contain as much fat as whole milk (Cook et al., p. 9).

Retail fluid supply (Q_s^{rf}) is estimated as a function of the ratio of the retail fluid price index to the wholesale fluid price index (P^{wf}), the ratio of the fuels and energy price index (*PFE*) to the wholesale fluid price index, lagged supply, the unemployment rate (*UNEMP*), a time trend, and the harmonic seasonal variables. The specification of the retail-to-wholesale price ratio and the energy price to the wholesale price ratio is consistent with the zero homogeneity assumption for prices. The wholesale fluid and energy prices represent two of the most important costs in fluid retailing. The two lagged dependent variables are included to capture short- and longer-term production capacity constraints.[9] The unemployment rate is used as a proxy for the state of the economy. The time trend is included to capture other determinants of supply such as labor costs in the retail fluid sector, which are unavailable.

Retail manufactured supply (Q_s^{rm}) is estimated as a function of the ratio of the retail manufactured price index to the wholesale manufactured price index (P^{wm}), the ratio of the average hourly wage rate in the manufactured sector (*MWAGE*) to the wholesale manufactured price index, lagged supply, and a harmonic seasonal variable. The wholesale manufactured price accounts for the largest portion of variable costs, and the manufactured wage rate measures labor costs in manufactured retailing. The energy price and unemployment rate were included in the initial estimation of this equation, but were subsequently omitted due to their coefficients being of the wrong sign. Also, the trend variable and *SIN*1 were omitted due to insignificant coefficients. The exclusion of *TIME* and *SIN*1 did not change the results of the estimation significantly.

Wholesale fluid supply (Q_s^{wf}) is estimated as a function of the ratio of the wholesale fluid price index to the Class I price for raw milk ($P^{I} = P^{II} + d$), the ratio of the fuels and energy price index to the Class I price, lagged supply, the unemployment rate, a time trend, and the harmonic seasonal variables. The Class I price is included because it represents the most important cost in fluid wholesaling.

Wholesale manufactured supply (Q_s^{wm}) is estimated as a function of the ratio of the wholesale manufacturing price index to the Class II

[7] All deflated price variables are defined as the nominal measure divided by the Consumer Price Index for all items (1967 = 100). The variables *COS*1 and *SIN*1 represent the first wave of the cosine and sine, respectively (Doran and Quilkey). The variable *POP* is the population of the United States.

[8] The impact of current and lagged fluid advertising expenditures on demand is specified as a second-order polynomial distributed lag with both end point restrictions imposed. The appropriateness of the end point restrictions was tested and not rejected. This specification is consistent with Ward and Dixon. The same specification is used for the manufactured advertising expenditures in the retail manufactured demand equation.

[9] The eigenvalues for this dynamic system have real parts all less than one in absolute value indicating the equation is stable. The stability condition also is satisfied for other dynamic supply equations presented here.

Table 2. *F*-Tests for the Price Reduced-Form Equations

Equation	Bias-Corrected Model		Conventional Model	
	$F(1,6)$	P-Value[a]	$F(22,6)$	P-Value
Retail Fluid Price (P^{rf})	.22	.66	1.54	.31
Retail Manufactured Price (P^{rm})	.61	.47	4.21 (Rejected)	.04
Wholesale Fluid Price (P^{wf})	3.09	.13	4.87 (Rejected)	.03
Wholesale Manufactured Price (P^{wm})			(Rejected)[b]	
Class II Price (P^{II})	.83	.40	5.52 (Rejected)	.02

[a] At $(1 - \alpha)$% confidence level, one rejects the model if the P-value is less than α.
[b] Based on the t-ratio on the Heckman-like correction term in equation (9).

price (P^{II}), the ratio of the manufactured wage to the Class II price, lagged supply, a policy dummy variable (*POLICY*), a time trend, and the harmonic seasonal variables. The Class II price is included because it represents the most important variable cost in manufactured wholesaling. The policy dummy variable (equal to one for the first quarter of 1984 through the second quarter of 1985 and the second quarter of 1986 through the third quarter of 1987) accounts for the significant reductions in raw milk supply due to the implementation of the Milk Diversion Program and the Dairy Termination Program, which had large impacts on the wholesale manufactured market. A first-order moving-average error structure is imposed to correct for serial correlation in the residuals. All the coefficients remain stable after imposing the moving-average term.

Tests for Selectivity Bias in the Conventional Model

As previously indicated, a significant t-statistic for the coefficient (σ) on the Heckman correction term in (10) signifies the existence of selectivity bias in the wholesale manufactured price reduced-form equation if ordinary least squares (instead of Tobit) is used. The t-statistic for the estimated σ is 6.4 using a maximum likelihood Tobit estimation procedure.[10] This supports the statistical relevancy of the Tobit procedure for the constrained wholesale manufactured price reduced-form equation.

The tests for the remaining four reduced-form equations of the unconstrained prices (retail fluid price, retail manufactured price, wholesale fluid price, and Class II price) are based on the Atkinson procedure discussed in (15) to (19). The P-values for the F-statistics are presented in table 2. At the 95% confidence level, the bias-corrected model cannot be rejected for all four equations. On the other hand, the conventional model is rejected for all of the price reduced forms except the retail fluid price. The result that the conventional model cannot be rejected for the retail fluid price is not that surprising because this market probably has the weakest linkage to the supported wholesale manufactured market.

The above tests provide statistical evidence that selectivity bias is not simply a problem for the price directly influenced by government intervention. It also affects other price reduced-form equations in the system.

Empirical Implications for Policy Analysis

While we have shown that the conventional model suffers from selectivity bias, it is useful to examine the differences in the magnitudes of estimated structural parameters between the two models. It is also useful to investigate whether the two models generate different policy conclusions. To provide the basis for these comparisons, the conventional model is estimated using two-stage least squares assuming the government purchase price is always binding. The estimation results are presented in table 3.

The estimated structural equations are similar to those of the bias-corrected model with respect to goodness of fit, t-values, Durbin-Watson and Durbin-h statistics. The major dif-

[10] The t-ratio for the estimate of σ using a Heckman two-step estimation procedure (Maddala, pp. 158–59) is 5.24.

Table 3. Estimated Structural Equations (The Conventional Model)

Retail Fluid Demand

$$\ln(Q_d^{rf}/POP) = \underset{(-14.61)}{-2.253} - \underset{(-2.13)}{.267}\ \ln(P^{rf}/INC) + \underset{(2.17)}{.149}\ \ln(PBEV/INC) + \underset{(1.96)}{.0025}\ \ln DGFA$$
$$+ \underset{(1.96)}{.004}\ \ln DGFA_{-1} + \underset{(1.96)}{.0045}\ \ln DGFA_{-2} + \underset{(1.96)}{.004}\ \ln DGFA_{-3} + \underset{(1.96)}{.0025}\ \ln DGFA_{-4}$$
$$- \underset{(-6.46)}{.176}\ \ln TIME - \underset{(-3.54)}{.028}\ SIN1 + \underset{(10.51)}{.082}\ COS1 + \underset{(3.15)}{.502}\ \mu_{d_{-1}}^{rf}$$

Adj. $R^2 = .87$ Durbin-Watson = 1.85

Retail Manufactured Demand

$$\ln(Q_d^{rm}/POP) = \underset{(-10.97)}{-2.601} - \underset{(-1.85)}{.655}\ \ln(P^{rm}/INC) + \underset{(1.55)}{.432}\ \ln(PMEA/INC) + \underset{(1.30)}{.0008}\ \ln DGMA$$
$$+ \underset{(1.30)}{.0013}\ \ln DGMA_{-1} + \underset{(1.30)}{.0014}\ \ln DGMA_{-2} + \underset{(1.30)}{.0013}\ \ln DGMA_{-3} + \underset{(1.30)}{.0008}\ \ln DGMA_{-4}$$
$$- \underset{(-1.48)}{1.061}\ \ln DPAFH + \underset{(2.82)}{.082}\ \ln TIME - \underset{(-4.71)}{.050}\ SIN1 - \underset{(-7.98)}{.085}\ COS1$$

Adj. $R^2 = .84$ Durbin-Watson = 2.08

Retail Fluid Supply

$$\ln Q_s^{rf} = \underset{(6.17)}{2.856} + \underset{(1.98)}{1.108}\ \ln(P^{rf}/P^{wf}) - \underset{(-3.74)}{.111}\ \ln(PFE/P^{wf}) - \underset{(-4.06)}{.016}\ UNEMP$$
$$+ \underset{(1.73)}{.230}\ \ln Q_{s_{-1}}^{rf} - \underset{(-2.13)}{.245}\ \ln Q_{s_{-4}}^{rf} - \underset{(-1.74)}{.001}\ TIME - \underset{(-3.94)}{.052}\ SIN1 + \underset{(8.23)}{.096}\ COS1$$

Adj. $R^2 = .90$ Durbin-$h = 1.75$

Retail Manufactured Supply

$$\ln Q_s^{rm} = \underset{(-2.09)}{-2.197} + \underset{(2.64)}{.897}\ \ln(P^{rm}/P^{wm}) - \underset{(-1.96)}{.506}\ \ln(MWAGE/P^{wm}) - \underset{(-2.95)}{.045}\ COS1$$
$$+ \underset{(2.30)}{.167}\ \ln Q_{s_{-1}}^{rm} + \underset{(6.20)}{.560}\ \ln Q_{s_{-4}}^{rm}$$

Adj. $R^2 = .93$ Durbin-$h = 1.36$

Wholesale Fluid Supply

$$\ln Q_s^{wf} = \underset{(3.30)}{1.950} + \underset{(2.72)}{.461}\ \ln(P^{wf}/(P^{II} + d)) - \underset{(-2.49)}{.085}\ \ln(PFE/(P^{II} + d)) - \underset{(-4.08)}{.016}\ UNEMP$$
$$+ \underset{(1.66)}{.221}\ \ln Q_{s_{-1}}^{wf} - \underset{(-1.83)}{.203}\ \ln Q_{s_{-4}}^{wf} - \underset{(-3.77)}{.003}\ TIME - \underset{(-3.44)}{.047}\ SIN1 + \underset{(8.33)}{.093}\ COS1$$

Adj. $R^2 = .90$ Durbin-$h = 1.13$

Wholesale Manufactured Supply

$$\ln Q_s^{wm} = \underset{(1.41)}{.285} + \underset{(1.19)}{1.117}\ \ln(P^{wm}/P^{II}) - \underset{(-2.26)}{.431}\ \ln(MWAGE/P^{II}) - \underset{(-3.83)}{.113}\ POLICY$$
$$+ \underset{(5.01)}{.422}\ \ln Q_{s_{-1}}^{wm} + \underset{(3.76)}{.335}\ \ln Q_{s_{-4}}^{wm} + \underset{(3.30)}{.00014}\ TIME^2 + \underset{(4.74)}{.100}\ SIN1 - \underset{(-6.14)}{.123}\ COS1$$
$$+ \underset{(3.54)}{.617}\ \mu_{s_{-1}}^{wm}$$

Adj. $R^2 = .96$ Durbin-$h = .25$

ference between the two models lies in the magnitudes of the price coefficients. In general, the conventional model has smaller own-price coefficients in the demand equations and larger price coefficients in the supply equations. For example, the own-price coefficients in the retail manufactured supply equations are .897 for the conventional model and .683 for the bias-corrected model. On the other hand, the own-price coefficients in the retail manufactured demand equations are $-.655$ for the conventional model and $-.928$ for the bias-corrected model.

To investigate whether the two models generate different policy conclusions, dynamic impulse analyses are conducted on the conventional and the bias-corrected models. Two policy variables are of interest: the government purchase price (P^g) and the Class I differential (d). The levels of these two variables are of interest because they have been the key policy instruments set by Congress and the Administration in the 1985 and the 1990 farm bills. It is assumed that the dairy sector is in a steady state in which all the variables are set at a three-year average of 1985–87. The two models are shocked with a permanent 10% increase in the government purchase price, and the impacts on the endogenous variables are simulated for 20 quarters. A similar analysis is conducted with a 10% shock in the Class I differential. The models are solved using the Gauss-Seidel method.

In general, the endogenous variables con-

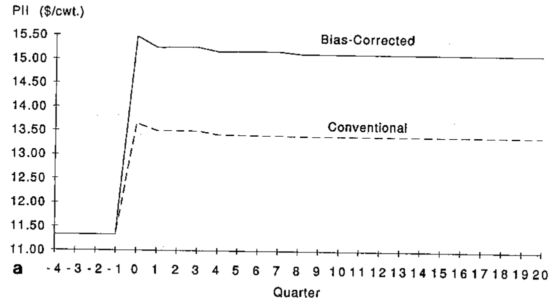


Figure 3a. Impact of 10% permanent shock in the government purchase price on the Class II price

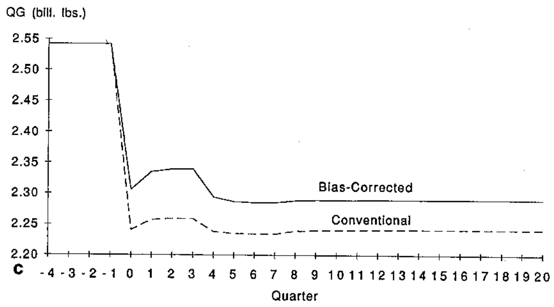


Figure 3c. Impact of 10% permanent shock in the government purchase price on government quantity

verge to a new steady state within two years regardless of which model is used. In addition, the pattern of the convergence from the two models is similar for most variables. However, the level of the time paths differs significantly for some variables, as illustrated in figures 3a–3d. In these figures, the preshock steady state (quarters -4 to -1) and the adjustment paths, resulting from the shock (at quarter 0), for the Class II price and government purchases are presented. With a permanent 10% shock in the government purchase price, the Class II price in the conventional and bias-corrected models reaches a new steady state of $13.40 and $15.12, respectively, from an old steady state of $11.33 (figure 3a). With a permanent 10% shock in the Class I differential, government purchases decrease from an old steady state of 2.54 billion pounds per quarter to 1.64 and 1.40 billion pounds, respectively, which represents an annual difference of about one billion pounds between the two models (figure 3b).

However, the differences between models are not dramatic for all variables. For example, with a permanent 10% shock in the government purchase price, government quantity in the conventional and bias-corrected models reaches a new steady state of 2.24 and 2.29 billion pounds per quarter, respectively (figure 3c). Also, with a permanent 10% shock in the Class I differential, the Class II price increases from an old steady state of $11.33 to $11.51 and $11.89 for the two models, respectively (figure 3d). It should be noted that while the absolute differences are small, the relative differences may be large. For instance, the latter case indicates that a 10% increase in the Class I differential results in a 2.5% increase in the Class II price when the conventional model is used, while this shock results in double that increase (5%) when the bias-corrected model is used.

These results apply to most of the other endogenous variables as well indicating that economic analysis of the dairy sector based on the conventional model may yield policy prescriptions that are substantially different from those

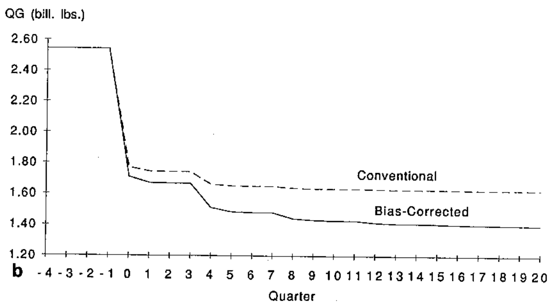


Figure 3b. Impact of 10% permanent shock in the Class I differential on government quantity

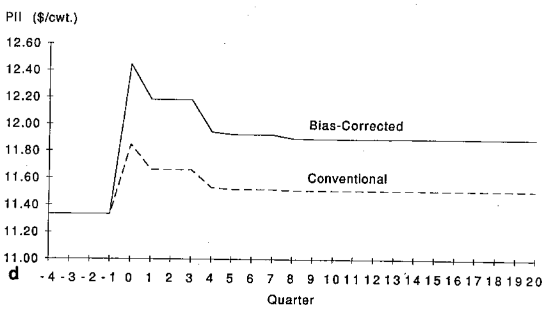


Figure 3d. Impact of 10% permanent shock in the Class I differential on the Class II price

based on the bias-corrected model. A similar conclusion is found when shocking other exogenous variables (e.g., income and advertising) and when different initial steady-state values (other than the 1985–87 averages) for the variables in the model are used in the simulation.

Summary

This article presented a multiple-market switching simultaneous system model for the dairy sector. It was argued that this model is necessary for the dairy sector in order to deal with selectivity bias caused by switching between two regimes: (*a*) a government support regime which exists when the price determined by competitive supply and demand conditions is below the government stipulated price and (*b*) a market equilibrium regime which occurs otherwise. The estimation procedure for the system is similar to conventional two-stage least squares in that an instrument is first obtained from the reduced-form equation and then is substituted into the structural equation estimation. However, special procedures are needed for the reduced-form estimation in order to correct for selectivity bias.

In general, both the bias-corrected and the conventional two-stage least squares models fit the data reasonably well. However, based on the Heckman two-step and Atkinson nonnested test results, the restrictions required for the conventional model are not supported by the data. It was shown that selectivity bias is not only apparent in the component of the system directly affected by government intervention but also exists in other markets in the dairy sector. In addition, the results from the impulse analyses indicate that economic analysis of the dairy sector based on the conventional model may yield policy prescriptions that are substantially different from those based on the bias-corrected model.

[*Received May 1990; final revision received April 1991.*]

References

Atkinson, A. C. "A Method for Discriminating Between Models." *J. Royal Statis. Soc., Series B* 32(1970): 323–45.

Binkley, J. K. "A Consideration in Estimating 'Almost Nonsimultaneous' Market Models." *Amer. J. Agr. Econ.* 67(1985):320–24.

Bureau of Economic Statistics, Inc. Economic Statistics Bureau of Washington DC. *Handbook of Basic Economic Statistics.* Washington DC, 1970–88.

Chavas, J.-P., and R. M. Klemme. "Aggregate Milk Supply Response and Investment Behavior on U.S. Dairy Farms." *Amer. J. Agr. Econ.* 68(1986):55–66.

Cook, H. L., L. Blakley, R. Jacobson, R. Knutson, R. Milligan, and R. Strain. *The Dairy Subsector of American Agriculture: Organization and Vertical Coordination.* North Central Project 117, Monograph 5, November 1978.

Doran, H. E., and J. J. Quilkey. "Harmonic Analysis of Seasonal Data: Some Important Properties." *Amer. J. Agr. Econ.* 54(1972):646–51.

Hausman, J. A. "Specification Tests in Econometrics." *Econometrica* 46(1978):1251–71.

Heckman, J. "The Common Structure of Statistical Models of Truncation, Sample Selection, and Limited Dependent Variables and a Simple Estimation for Such Models." *Ann. Econ. Socio. Measure.* 5(1976):475–92.

Johnson, N. L., and S. Kotz. *Distributions in Statistics: Continuous Multivariate Distributions.* New York: John Wiley, 1972.

Judge, G. G., W. E. Griffiths, R. C. Hill, and T.-C. Lee. *The Theory and Practice of Econometrics.* New York: John Wiley and Sons, Inc., 1980.

Kaiser, H. M., D. H. Streeter, and D. J. Liu. "Welfare Comparisons of U.S. Dairy Policies With and Without Mandatory Supply Control." *Amer. J. Agr. Econ.* 70(1988):848–58.

LaFrance, J. T., and H. de Gorter. "Regulation in a Dynamic Market: The U.S. Dairy Industry." *Amer. J. Agr. Econ.* 67(1985):821–32.

Leading National Advertisers, Inc. *Leading National Advertisers.* New York, 1975–88.

Liu, D. J., and O. D. Forker. "Generic Fluid Milk Advertising, Demand Expansion, and Supply Response: The Case of New York City." *Amer. J. Agr. Econ.* 70(1988):229–36.

Liu, D. J., H. M. Kaiser, O. D. Forker, and T. D. Mount. "An Economic Analysis of the U.S. Generic Dairy Advertising Program Using an Industry Model." *N. East. J. Agr. Resour. Econ.* 19(1990):37–48.

———. "The Economic Implications of the U.S. Generic Dairy Advertising Program: An Industry Model Approach." A.E. Res. 89-22, Department of Agricultural Economics, Cornell University, November 1989.

Maddala, G. S. *Limited-Dependent and Qualitative Variables in Econometrics.* Cambridge: Cambridge University Press, 1983.

Phlips, L. *Applied Consumption Analysis.* New York: North-Holland, 1983.

U.S. Department of Agriculture. Agricultural Marketing Service. *Federal Milk Order Market Statistics.* Washington DC, 1970–88a.

U.S. Department of Agriculture. Economic Research Service. *Dairy Situation and Outlook.* Washington DC, 1970–88b.

U.S. Department of Labor, Bureau of Labor Statistics. *Consumer Price Index.* Washington DC, 1970–88a.

———. *Employment and Earnings.* Washington DC, 1970–88b.

———. *Producer Price Index (and Wholesale Price Index).* Washington DC, 1970–88c.

Ward, R. W., and B. L. Dixon. "Effectiveness of Fluid Milk Advertising Since the Dairy and Tobacco Adjustment Act of 1983." *Amer. J. Agr. Econ.* 71(1989): 730–40.

Appendix

It is shown here that, under the log-linear structural specification, normality in the structural error terms implies normality in the corresponding log price reduced-form error terms regardless of whether the market is in a competitive or government support regime.

To simplify, consider a two-market model consisting of only a retail manufactured market and a wholesale manufactured market, with a predetermined quantity of wholesale manufactured supply at any given point in time. As in the full model, the government sets a purchase price at the wholesale level and stands ready to buy the excess supply at that price. The retail demand, supply, and equilibrium condition are described in text equations (1a), (1b), and (1c). The wholesale demand is described by text equation (3b). The wholesale equilibrium condition is (3c) when the market is competitive and (3c′) when the market is government supported. The wholesale manufactured supply in (3a) is not needed for this illustration because the supply is assumed to be predetermined.

In the case of the market equilibrium regime, the retail price can be solved using (1b), (1c), (3b), and (3c):

$$\text{(A.1)} \qquad \ln P^{rm} = A - \mu_d^{rm}/\beta_d^{rm},$$

where $A \equiv \{\ln(Q_s^{wm} - QSP - \Delta IVN) - \gamma_d^{rm} \ln Z_d^{rm}\}/\beta_d^{rm}$. Given $\ln P^{rm}$ in (A.1), we solve for the wholesale price using (1a), (1c), (3b), and (3c):

$$\text{(A.2)} \qquad \ln P^{wm} = B + (\alpha_s^{rm}\mu_d^{rm} - \beta_d^{rm}\mu_s^{rm})/(\beta_d^{rm}\beta_s^{rm}),$$

where $B \equiv \{(\beta_d^{rm} - \alpha_s^{rm})\ln(Q_s^{wm} - QSP - \Delta INV) + \alpha_s^{rm}\gamma_d^{rm}\ln Z_d^{rm} - \alpha_s^{rm}\beta_d^{rm}\ln Z_s^{rm}\}/(\beta_d^{rm}\beta_s^{rm})$. Upon inspecting the error components of (A.1) and (A.2), it is clear that the log price reduced-form error terms will be normally distributed if the log-linear structural error terms are normal.

In the case of the government support regime, we set $\ln P^{wm} = \ln P^g$. Then, from text equations (1a), (1b), and (1c), we solve for the retail price:

$$\text{(A.3)} \qquad \ln P^{rm} = C + (\mu_s^{rm} - \mu_d^{rm})/(\beta_d^{rm} - \alpha_s^{rm}),$$

where $C \equiv \{\gamma_s^{rm}\ln Z_s^{rm} - \gamma_d^{rm}\ln Z_d^{rm} + \beta_s^{rm}\ln P^g\}/(\beta_d^{rm} - \alpha_s^{rm})$. From the error component of (A.3), it is clear that normality of the log price reduced-form error is also preserved in the case of the government support regime. Thus, we have shown that under the log-linear structural specification, normality in the structural error terms implies normality in the corresponding log price reduced-form error terms regardless of which regime occurs.