Journal of Agricultural and Resource Economics 20(2):301–315

Market Conduct under Government Price Intervention in the U.S. Dairy Industry

Donald J. Liu, Chin-Hwa Sun, and Harry M. Kaiser

The degree of market power exercised by fliud and manufactured processors in the U.S. dairy industry is estimated. Appelbaum's quantity-setting conjectural variation approach is cast into a switching regime framework to account for the two market regimes created by the existence of the dairy price support program: (*a*) government supported regime (market price is at the support price) and (*b*) market equilibrium regime (market price is above the support price). The model is also used to test whether government price intervention has a pro-competitive or anti-competitive influence on market conduct.

Key words: market conduct, switching regime, U.S. dairy industry

Introduction

The U.S. dairy industry has become more concentrated over the last several decades. For example, between 1963 and 1987, the 20-firm concentration ratios for wholesale butter, cheese, and fluid milk companies increased from 31% to 94%, 59% to 68%, and 48% to 67%, respectively (U.S. Census of Manufacturers). These concentration ratios suggest that models of the dairy industry should account for the market power of processors.

A framework that became popular in the 1980s for assessing the degree of market power was developed by Appelbaum. Rather than assuming a certain market conduct, the Appelbaum procedure uses the concept of conjectural variation, which is estimated endogenously as a measure of the degree of market power.[1] There have been several applications of this technique to agricultural industries (Schroeter; Schroeter and Azzam 1990, 1991; Azzam and Pagoulatos; Buschena and Perloff; Durham and Sexton; Wann and Sexton; Azzam and Park). However, with few exceptions, models of the U.S. dairy industry have assumed that the market is perfectly competitive (e.g., Kaiser, Streeter, and Liu; La France and de Gorter). To our knowledge Suzuki et al. is the only U.S. dairy study that incorporated a market power parameter of cooperatives and fluid processors. However, the role of government intervention was ignored in Suzuki et al. In the U.S. dairy industry, government intervention through the dairy price support program causes prices to be determined under two different structural regimes: a "market equilibrium" regime, where the market price is above the support price, and a "government supported" regime, where the support price is the effective price. In a recent study Liu et al. presented an econometric model that allows for endogenous switching between the two market regimes. Under this framework government intervention becomes

---

Senior authorship is equally shared. The authors, respectively, are assistant professor in the Department of Applied Economics at the University of Minnesota, associate professor in the Institute of Fisheries Economics at the National Taiwan Ocean University, and associate professor in the Department of Agricultural, Resource, and Managerial Economics at Cornell University.

Support for this research was provided by the New York Milk Promotion Advisory Board.

[1] Applebaum's procedure involves deriving the first-order condition of the profit-maximizing oligopolist, using a dual framework. The markup term of price over marginal cost appearing in the first-order condition contains both the slope of the demand curve and the so-called "conjectural variation" to be discussed shortly. The first-order condition is then estimated in

part of the market structure, since the reduced-form equations for each regime are different. However, Liu et al. assumed no market power on the part of industry participants.[2]

Given the importance of government programs in many of the U.S. and foreign agricultural industries, an obvious question is how to estimate the market power of industry participants when there is government intervention in the price formation process. The task calls for merging the literature on market power with that on switching regime estimation. This article presents a framework for that purpose and then estimates the degree of selling power exercised by U.S. fluid and manufactured dairy processors using that framework.[3] The study also examines whether the conduct of processors is different between the two market regimes, a relevant public policy issue.

A Conceptual Framework

Consider an oligopolistic industry where individual firms face a downward sloping aggregate demand curve and there is a government price support program for the product. Denote the product by m. The demand equation is specified in inverse form as:

$$P^m = P^m(Q^{md}, Z^m), \tag{1}$$

where P^m is the price of product m, Q^{md} is the aggregate demand quantity, and Z^m is a vector of demand shifters.

Due to government price supports, the observed price (P^{m*}) depends on whether the government support price (P^g) is binding. In the market equilibrium regime, the observed price is higher than the government support price and, hence, is equal to P^m plus a shock (ε^m) to the demand equation in (1):

$$P^{m*} = P^m + \varepsilon^m \qquad \text{if } P^m + \varepsilon^m > P^g. \tag{2a}$$

Under the government supported regime $P^m + \varepsilon^m \leq P^g$, and hence, the observed price is equal to P^g:

$$P^{m*} = P^g \qquad \text{if } P^m + \varepsilon^m \leq P^g. \tag{2b}$$

There is a distinction made between supply and demand quantities (Q^{ms} vs. Q^{md}), because they need not be equal, due to possible government purchases (Q^g). More explicitly, one has

$$Q^{ms} = \begin{cases} Q^{md} + Q^g & \text{in the government supported regime,} \\ Q^{md} & \text{in the market equilibrium regime.} \end{cases} \tag{3}$$

The supply relation for an individual producer or processor (henceforth processor) is given by the first-order condition of her maximization problem. Facing the demand equation

[2]Also see Shonkwiler and Maddala for a treatment of modeling agricultural markets with government price support programs.

[3]Ideally, a complete model would include the selling and buying power of both processors. However, since this would greatly increase the complexity of the switching regime estimation, this study focuses solely on the selling power of processors.

in (1) and the switching scheme in (2), the ith processor maximizes the profit by choosing the optimal supply quantity:

(4) $$\max_{\{q_i^m\}} \pi_i^m = E[P^{m*}]\, q_i^m - C_i^m(q_i^m, W^m),$$

where $E[P^{m*}]$ is the expected output price; q_i^m is the ith processor's output supply quantity (with $\Sigma_i q_i^m = Q^{ms}$); and C_i^m is the cost function, which depends on q_i^m and a vector of parametric variable costs (W^m).

The first-order condition for the optimization problem is

(5) $$E[P^{m*}] - \frac{\partial C_i^m}{\partial q_i^m} + \left(\frac{\partial E[P^{m*}]}{\partial q_i^m}\right) q_i^m = 0.$$

The last term in (5), $\partial E[P^{m*}] / \partial q_i^m$, captures the ith processor's perceived effect of a change in her q_i^m on the manufactured price, $E[P^{m*}]$. This term is analogous to the conventional market power term in a monopolist's problem, except in this case the price effect also accounts for the perceived quantity change (arising from a change in q_i^m) of other suppliers.

The expected price $E[P^{m*}]$ depends, in part, on the associated probabilities of the market equilibrium and government supported regimes. Define the probability that the government supported regime occurs as $\Phi(\alpha)$ and the probability that the market equilibrium regime occurs as $1-\Phi(\alpha)$:

(6a) $$\text{Prob}(P^m + \varepsilon^m \le P^g) = \Phi(\alpha), \quad \text{and}$$

(6b) $$\text{Prob}(P^m + \varepsilon^m > P^g) = 1 - \Phi(\alpha),$$

where $\Phi(\alpha)$ is the cumulative standard normal of ε^m evaluated at $\alpha \equiv (P^g - P^m)/\sigma^m$, and σ^m is the standard deviation of ε^m. Hence, the unconditional expectation for P^{m*} is

(7) $$E[P^{m*}] = (1-\Phi)\, E[P^{m*} \mid P^m + \varepsilon^m > P^g] + \Phi P^g.$$

Given (2a), the first term on the right-hand side of (7) can be expressed as (Maddala, pp. 158–59):

(8) $$E[P^{m*} \mid P^m + \varepsilon^m > P^g] = P^m + \sigma^m \phi / (1-\Phi),$$

where ϕ is the standard normal density, again evaluated at α. The last term in (8) is similar to Heckman's bias correction term for selectivity bias arising from price censoring caused by the price support program. Upon substituting (8) into (7), the unconditional expectation for P^{m*} is

(9) $$E[P^{m*}] = (1-\Phi)\left\{P^m + \sigma^m \phi / (1-\Phi)\right\} + \Phi P^g.$$

The expression in (9) can be substituted for the first term in the first-order condition in (5). In addition, (9) can be used to derive the last term in (5), $\partial E[P^{m^*}]/\partial q_i^m$. Differentiate (9) with respect to q_i^m and make use of the fact that Φ and ϕ are both evaluated at $\alpha \equiv (P^g - P^m)/\sigma^m$:

$$(10) \qquad \frac{\partial E[P^{m^*}]}{\partial q_i^m} = (1-\Phi)\frac{\partial P^m}{\partial q_i^m} + \frac{\partial(1-\Phi)}{\partial P^m}\frac{\partial P^m}{\partial q_i^m}P^m + \sigma^m\frac{\partial \phi}{\partial P^m}\frac{\partial P^m}{\partial q_i^m} + \frac{\partial \Phi}{\partial P^m}\frac{\partial P^m}{\partial q_i^m}P^g.$$

Let $\xi \equiv P^g - P^m$ and, hence, $\alpha \equiv \xi/\sigma^m$. Using the derivative rules that $\partial\Phi/\partial\xi = \phi/\sigma^m$ and $\partial\phi/\partial\xi = -\phi\xi/\sigma^{m^2}$ (Maddala, p.365), (10) can be rewritten as:

$$(11) \qquad \frac{\partial E[P^{m^*}]}{\partial q_i^m}q_i^m = \left\{(1-\Phi) + \frac{\phi}{\sigma^m}P^m + \frac{P^g - P^m}{\sigma^m}\phi - \frac{\phi}{\sigma^m}P^g\right\}\frac{\partial P^m}{\partial q_i^m}q_i^m$$
$$= (1-\Phi)\frac{\partial P^m}{\partial q_i^m}q_i^m.$$

Since the terms associated with P^g cancel out, it is clear that the remaining term, $(1-\Phi)\partial P^m/\partial q_i^m q_i^m$, in the second line of (11), pertains to the case where the market equilibrium regime prevails. In this regime, equation (3) is simply $Q^{md} = Q^{ms}$. To further manipulate (11), one seeks an expression for $(\partial P^m/\partial q_i^m)q_i^m$. Denote $\partial Q^{ms}/\partial q_i^m$ as the *i*th processor's conjectural variation pertaining to the aggregate supply quantity of the product. Applying the chain rule to (1) and making use of the fact that, in the market equilibrium regime, $Q^{md} = Q^{ms}$ (and, hence, $\partial Q^{md}/\partial Q^{ms}$ and Q^{ms}/Q^{md} are both equal to one), one obtains

$$(12) \qquad \frac{\partial P^m}{\partial q_i^m}q_i^m = \left\{\frac{\partial P^m}{\partial Q^{md}}\frac{\partial Q^{md}}{\partial Q^{ms}}\frac{\partial Q^{ms}}{\partial q_i^m}\right\}q_i^m = -P^m\eta^{mm}\frac{Q^{ms}}{Q^{md}}\frac{\partial Q^{md}}{\partial Q^{ms}}\lambda_i^m = -P^m\eta^{mm}\lambda_i^m,$$

where $\eta^{mm} \equiv -\partial(\ln P^m)/\partial(\ln Q^{md})$, which is the price flexibility with respect to commercial quantity; and $\lambda_i^m \equiv \partial(\ln Q^{ms})/\partial(\ln q_i^m)$, which is the *i*th processor's conjecture elasticity of aggregate supply with respect to a change in q_i^m.

If the individual processor behaves competitively, she would conjecture that, as she changes her output, other firms will adjust their quantities in such a way that the price the individual faces will remain unchanged. That is, $\lambda_i^m = 0$. In contrast, if the individual processor has monopoly power, any change in her supply will perfectly coincide with the change in the aggregate supply, that is, $\lambda_i^m = 1$. In general, $\lambda_i^m \in [0, 1]$. Substituting (12) into (11), and then the resulting expression into (5) for $\partial E[P^m]/\partial q_i^m q_i^m$, the first-order condition can finally be expressed as:

$$(13) \qquad \frac{[(1-\Phi)P^m + \sigma^m\phi + \Phi P^g] - \partial C_i^m/\partial q_i^m}{P^m} = (1-\Phi)\eta^{mm}\lambda_i^m.$$

Notice that the bracketed terms in the numerator in (13) are the expected output price, $E[P^{m^*}]$, and hence, the left-hand side of (13) is the Lerner index measuring the price-cost margin.

The right-hand side of (13) indicates that the price-cost margin is a function of market regime probability $(1-\Phi)$, conjectural elasticity of the processor (λ_i^m), and the price flexibility of the demand function (η^{mm}).

To summarize, the model includes a demand function with government price intervention, (1) and (2); a supply relation, (13); and a market equilibrium condition with possible government purchases, (3). Therefore, there are four equations in the model. In the case of the market equilibrium regime, the endogenous variables contained in the four equation system are the following: P^m, P^{m*}, Q^{md}, and Q^{ms}. In the case of the government supported regime, Q^g replaces P^{m*} $(\because P^{m*} \equiv P^g)$ as an endogenous variable.

The Switching Dairy Model

The dairy model used in this study includes a manufactured dairy product subsector and a fluid milk subsector. The model focuses on the wholesale processing level of the dairy industry, because government price intervention occurs at this level. Under the dairy price support program, the government supports the farm milk price indirectly by agreeing to buy unlimited quantities of manufactured dairy products (cheese, butter, and nonfat dry milk) in the wholesale market at announced "purchase prices." With minor modifications the framework presented in the previous section is appropriate for the manufactured dairy product subsector.

The retailer's demand equation for manufactured dairy products in the wholesale market is specified in inverse form as:

$$P^m = P^m(Q^{md}, Q^f, Z^m), \tag{14}$$

where the superscript m is used to denote manufactured dairy product and f the fluid milk product. Equation (14) is the same as (1), except now the fluid quantity (Q^f) is also included as a right-hand side variable, accounting for the cross-quantity effect on price. Notice that no distinction is made between fluid milk supply and demand (i.e., $Q^{fs} = Q^{fd} \equiv Q^f$), because there is no direct government intervention in this market. With the additional cross-quantity term, (12) is modified:[4]

$$\frac{\partial P^m}{\partial q_i^m} q_i^m = -P^m \left\{ \eta^{mm} - \eta^{mf} \frac{Q^{ms}}{Q^f} \right\} \lambda_i^m, \tag{15}$$

where $\eta^{mf} \equiv -\partial(\ln P^m)/\partial(\ln Q^f)$.

To simplify the estimation, it is assumed that milk processing at the wholesale level follows a Leontief-type technology of fixed proportions between farm milk and other inputs. With (12) being replaced by (15) and the fixed proportions assumption, the first-order condition in (13) becomes

[4]With Q^f appearing as an additional argument for P^m, one adds $(\partial P^m / \partial Q^f)(\partial Q^f / \partial q_i^m)$ to the curly bracketed term in the first line of (12). The term $\partial Q^f / \partial q_i^m$ is interpreted as the ith manufactured product processor's conjectural variation pertaining to the aggregate fluid supply quantity. Details on the derivation can be obtained from the authors upon request.

(16) $$\frac{\left[(1-\Phi)\,P^{m}+\sigma^{m}\phi+\Phi P^{g}\right]-P^{II}-\partial C_i^{m}/\partial q_i^{m}}{P^{m}}=(1-\Phi)\left(\eta^{mm}-\eta^{mf}\,Q^{ms}/Q^{f}\right)\lambda_i^{m},$$

where P^{II} is the Class II price that manufactured dairy processors must pay for farm milk input,[5] and C_i^m is now defined as the cost function associated with other variable inputs.

The Fluid Milk Subsector

The retailer's demand equation for fluid milk in the wholesale market is specified in inverse form as follows:

(17) $$P^{f}=P^{f}(Q^{f},Q^{md},Z^{f}),$$

where Z^f is a vector of fluid demand shifters. Denoting ε^f as a shock to the fluid demand equation, the observed fluid price is

(18) $$P^{f*}=P^{f}+\varepsilon^{f}.$$

Since there is no direct government price intervention in the fluid milk market, $E[P^{f*}]=P^f$.

Regarding the supply side of the fluid submodel, consider the following profit maximization problem for individual fluid processor *j*:

(19) $$\max_{\{q_j^f\}}\pi_j^{f}=(P^{f}-P^{II}-d)\,q_j^{f}-C_j^{f}(q_j^{f},W^{f}),$$

where $P^{II}+d$ is the Class I farm milk price, which is equal to the Class II price plus the exogenous Class I differential (d); q_j^f is the jth fluid processor's supply quantity (with $\Sigma_j\, q_j^f=Q^f$); and C_j^f is the processing cost function, which depends on q_j^f and a vector of parametric variable processing costs (W^f).

Upon manipulation, the fluid processor's first-order condition can be written as the following price-cost margin expression:[6]

(20) $$\frac{P^{f}-P^{II}-d-\partial C_j^{f}/\partial q_j^{f}}{P^{f}}=\left[\eta^{ff}-(1-\Phi)\,\eta^{fm}\,Q^{f}/Q^{md}\right]\lambda_j^{f},$$

where $\eta^{ff}\equiv-\partial(\ln P^{f})/\partial(\ln Q^{f})$, $\eta^{fm}\equiv-\partial(\ln P^{f})/\partial(\ln Q^{md})$, and $\lambda_j^{f}\equiv\partial(\ln Q^{f})/\partial(\ln q_j^{f})$.

[5]Under the federal milk marketing order system, manufactured dairy product processors pay the Class II price for their milk, while the fluid milk processors pay the Class I price which is equal to the Class II price plus a fixed Class I differential.

[6]Similar to the manufactured dairy products case, the derivation begins with applying the chain rule to the demand equation in (17). Details of the derivation can be obtained from the authors upon request.

To facilitate time-series data estimation, the individual processor's first-order conditions in (16) and (20) are aggregated. Assuming a generalized Leontief technology, the aggregate processing cost function for each subsector k ($k = m$ and f) can be written as:

$$C^k(Q^k, W^k) = Q^k \Sigma_i \Sigma_j \beta_{ij}^k (W_i^k W_j^k)^{1/2} + \Sigma_i \beta_i^k (W_i^k)^{1/2},$$

where the subscripts i and j now denote processing inputs, rather than firms. The aggregate marginal cost for the kth subsector is $\Sigma_i \Sigma_j \beta_{ij}^k (W_i^k, W_j^k)^{1/2}$. The aggregated first-order conditions can then be written as:

(21)
$$P^{ll} = (1-\Phi)P^m + \sigma^m \phi + \Phi P^g - \Sigma_i \Sigma_j \beta_{ij}^m (W_i^m W_j^m)^{1/2}$$
$$-P^m (1-\Phi)\left(\eta^{mm} - \eta^{mf} Q^{ms} / Q^f\right)\lambda^m, \text{ and}$$

(22)
$$P^{ll} + d = P^f - \Sigma_i \Sigma_j \beta_{ij}^f (W_i^f W_j^f)^{1/2} - P^f\left[\eta^{ff} - (1-\Phi)\eta^{fm} Q^f / Q^{md}\right]\lambda^f,$$

where, as discussed in Appelbaum, λ^k is the aggregate conjectural elasticity (measuring the average industry conduct) for processors in the kth subsector.

To give some structure to the average industry conduct parameters in (21) and (22), it is hypothesized that λ^k ($k = m$ and f) is a function of the probability of the market equilibrium regime occurring $(1-\Phi)$. Further, since λ^k lies between zero and one, the following logistic function is specified:

(23)
$$\lambda^k = 1 / \left\{1 + \exp\left[\gamma^k - \delta^k (1-\Phi)\right]\right\}.$$

Including $1-\Phi$ as an explanatory variable for λ^k can provide insight toward the issue of whether competition is more pervasive in market equilibrium or government supported regimes. For example, according to Rotemberg and Saloner, one might expect to find a negative relationship between λ^k and $1-\Phi$, because individual dairy processors, in an attempt to capture a larger share of the "boom" market, are inclined to behave more competitively in the market equilibrium regime.

Substituting (23) into (21) and (22), the aggregate first-order conditions for manufactured and fluid processors become

(24)
$$P^{ll} = (1-\Phi)P^m + \sigma^m \phi + \Phi P^g - \Sigma_i \Sigma_j \beta_{ij}^m (W_i^m W_j^m)^{1/2}$$
$$-\frac{P^m (1-\Phi)\left(\eta^{mm} - \eta^{mf} Q^{ms} / Q^f\right)}{1 + \exp\left[\gamma^m - \delta^m (1-\Phi)\right]}, \text{ and}$$

(25)
$$P^{ll} + d = P^f - \Sigma_i \Sigma_j \beta_{ij}^f (W_i^f W_j^f)^{1/2} - \frac{P^f\left[\eta^{ff} - (1-\Phi)\eta^{fm} Q^f / Q^{md}\right]}{1 + \exp\left[\gamma^f - \delta^f (1-\Phi)\right]}.$$

The Closure

To close the model, the farm component is briefly introduced. Given the Leontief fixed proportions assumption between farm milk and other processing inputs, the quantities of wholesale fluid and manufactured products can be expressed on a farm milk equivalent basis. Then, Q^{ms} and Q^{f} can also be used to denote the derived demand for farm milk of dairy processors at the farm level. The linkage between the farm and wholesale markets can be written as follows:

$$\bar{Q} = Q^{ms} + Q^{f}, \tag{26}$$

where $\bar{Q}$ is the farm milk supply, assumed to be predetermined due to lags in farm milk production.

To summarize, the wholesale component of the model includes the following: a wholesale manufactured product demand function with government price intervention [(14) and (2)]; a wholesale manufactured product supply relation (24); a wholesale fluid demand function [(17) and (18)]; a wholesale fluid supply relation (25); a wholesale manufactured product equilibrium condition with possible government purchases (3); and a wholesale fluid equilibrium condition (imposed by using a common notation, i.e., $Q^{fd} = Q^{fs} \equiv Q^{f}$). The farm component of the model includes a farm milk demand function, a farm milk supply function, and a farm equilibrium condition. The predetermined farm milk supply assumption yields farm milk supply = $\bar{Q}$. Given that all quantity variables are expressed on an equivalent basis, farm milk demand = Q^{ms} + Q^{f}. Thus, the farm component of the model is concisely captured by the farm-wholesale linkage (26). There are eight equations in the model containing eight endogenous variables. In the case of the market equilibrium regime, the endogenous variables are as follows: P^{m}, P^{m*}, P^{f}, P^{f*}, P^{ll}, Q^{md}, Q^{ms}, and Q^{f}. In the case of the government supported regime, Q^{g} replaces P^{m*} ($\because P^{m*} \equiv P^{g}$) as an endogenous variable.

The Estimation

The estimation procedure is similar to conventional two-stage (nonlinear) least squares, with several exceptions. The structural equations to be estimated are the wholesale manufactured and fluid demand functions and supply relations. Similar to the two-stage least squares procedure, the first-stage involves estimating instruments for the endogenous variables in the right-hand side of the structural equations, and the second stage consists of substituting the instruments into the structural equations which are then estimated.

Instruments for the quantity variables appearing on the right-hand side of the structural equations are first obtained by regressing the quantity variables on all the exogenous variables and their one-period to four-period lags. Given the quantity instruments, the two inverse demand equations are estimated. Specifically, the manufactured product inverse demand function is estimated by applying a maximum likelihood tobit procedure to (14) and (2), and the fluid inverse demand function is estimated by using ordinary least squares on (17) and (18). The tobit procedure is needed for the manufactured demand function because of the limited dependent variable problem associated with the manufactured price; as indicated by (2), the manufactured price is constrained to be no less than the government purchase price.

In addition to the quantity variables, the right-hand sides of the supply relations in (24) and (25) involve other endogenous variables whose instruments must also be obtained. From the tobit estimation of the manufactured demand function, one obtains instruments for Φ, ϕ and P^m, as well as estimates of η^{mm}, η^{mf} and σ^m. From the ordinary least squares estimation of the fluid demand function, one obtains an instrument for P^f, as well as estimates of η^{ff} and η^{fm}. Upon substituting the obtained instruments (for quantity variables, P^m, P^f, Φ, and ϕ) and estimates (of η^{mm}, η^{mf}, η^{ff}, η^{fm}, and σ^m) into (24) and (25), the two first-order conditions can then be estimated. Rather than using single-equation estimation, the two first-order conditions are estimated as a system of nonlinear seemingly unrelated equations because P^{II} and P^{I} are related by an exogenous Class I price differential. From the system estimation, one obtains estimates of the remaining parameters (β^k_{ij}, γ^k, and δ^k; k = m and f).

While the two-stage procedure on a structural equation system with limited dependent variables is asymptomatically equivalent to a maximum likelihood estimation of the system, the conventionally computed second-stage standard errors on the structural parameters are biased (Maddala). The asymptotic theory for the above two-stage estimation method has been derived by Lee and may be used to correctly compute standard errors for the second-stage coefficients. However, as pointed out by Cornick and Cox, such theory is both complicated and not very general (i.e., the asymptotic covariance matrices have to be derived for each permutation of the model). Hence, a bootstrapping procedure after the fashion of Cornick and Cox is adopted to compute the second-stage standard errors of the structural coefficients.[7]

Empirical Results

Quarterly time series data from 1975 through 1992 are used to estimate the model. Variable definition and source of data are given in table 1. Since time-series data are used in the estimation, all the price variables in the model are deflated by the consumer price index for all items. Table 2 presents the empirical results for the two inverse demand equations. Both inverse demand equations are estimated in double-logarithmic form and as a function of commercial manufactured and fluid demand quantities (Q^{md} and Q^f); the consumer price indices for nonalcoholic beverages (*CPIBEV*), fats and oils (*CPIFAT*), and away-from-home food (*CPIAFH*); quarterly dummy variables (*Quarter-1*, *Quarter-2*, and *Quarter-3*); and generic manufactured/fluid advertising expenditures (*GMA*/*GFA*). The quarterly dummies are to capture demand seasonality, while the advertising expenditures account for the impact on demand of generic dairy promotion activities.[8] Autoregressive terms (*AR*) for the residuals are added to the demand equations to correct for serial correlation.

The estimated manufactured and fluid own-price flexibility coefficients are both negative, confirming that the demand curves are downward sloping. The estimated cross-price flexibility coefficients in both demand equations are negative, indicating that the two dairy products are gross substitutes. Except for *CPIBEV* in the fluid demand equation, the coefficients for the three price index variables are positive in both equations, suggesting a

[7]The procedure involves re-estimating the model for each bootstrap data set. The number of replications is 350.

[8]To capture the carryover effect of advertising, *GMA* and *GFA* are specified as a second-order polynomial distributed lag function of the previous four quarters' advertising expenditures, with end-point restrictions imposed for *GFA* but not for *GMA*. Imposition of the end-point restrictions for *GMA* is difficult because the manufactured demand equation is estimated by the tobit procedure.

Table 1. Variable Definitions and Data Sources

Variable	Definition	Unit	Source[a]
Q^{ms}	Wholesale manufactured supply	bil. lbs. of milkfat equivalent	DSO
Q^{md}	Wholesale manufactured demand	bil. lbs. of milkfat equivalent	DSO
Q^f	Wholesale fluid supply and demand	bil. lbs. of milkfat equivalent	DSO
P^m	Wholesale manufactured product price	\$/cwt	DSO
P^f	Wholesale fluid milk price	\$/cwt	DSO
P^g	Government manufactured product purchase price	\$/cwt	DSO
P^{II}	Class II price	\$/cwt	FMOM
d	Class I price differential	\$/cwt	FMOM
CPIFAT	Consumer price index for fats and oil	1967=100	CPI
CPIBEV	Consumer price index for non-alcoholic beverages	1967=100	CPI
CPIAFH	Consumer price index for away-from-home food	1967=100	CPI
PPIFE	Producer price index for fuel and energy	1967=100	EE
WAGE	Average hourly wage in food manufacturing sector	\$/hr.	EE
GMA	Generic manufactured product advertising expenditures	\$1,000	LNA
GFA	Generic fluid advertising expenditures	\$1,000	LNA

[a]Detailed citations are in the list of references.

substitution relationship between the dairy product in question and the food groups represented by the price indices. The coefficients for generic advertising expenditures are positive in both the fluid and manufactured demand equations but statistically significant only in the fluid case.[9] Finally, the estimated σ^m in the tobit equation is significantly different from zero, corroborating the importance of correcting for selectivity bias arising from the dairy price support program.

The estimated equations for the first-order conditions in (24) and (25) are presented in table 3. In this table, *PPIFE* is the producer price index for fuel and energy, and *WAGE* is the average hourly wage in the manufacturing sector of the general economy. These two prices are included to reflect the variable processing costs (W) appearing in (24) and (25). Similar to the demand equations, an autoregressive term for the residuals is added to each of the two first-order conditions to correct for serial correlation.

[9]Deleting the advertising variable from the manufactured demand equation does not change in any significant way the estimated coefficients of the remaining variables. Hence, it is left in the equation to be consistent with the fluid demand equation.

Table 2. Estimated Manufactured and Fluid Inverse Demand Equations (Double-Log)

	Manufactured Equation		Fluid Equation	
Variable	Estimated Coefficient	*t*-Value	Estimated Coefficient	*t*-Value
Intercept	5.799	7.3	1.405	4.0
Quarter-1	− 0.104	− 2.9	− 0.043	− 3.3
Quarter-2	− 0.170	− 4.2	− 0.040	− 2.4
Quarter-3	− 0.138	− 3.7	− 0.033	− 2.0
$\ln(Q^{md})$	− 0.136	− 0.7	− 0.296	− 3.9
$\ln(Q^{f})$	− 2.818	− 7.9	− 0.841	− 5.4
ln(*CPIBEV*)	0.081	0.6	− 0.160	− 3.1
ln(*CPIAFH*)	1.470	2.4	0.081	0.4
ln(*CPIFAT*)	0.731	1.8	0.724	6.4
GFA[a]			0.013	3.8
GMA1[a]	− 0.001	− 0.1		
GMA2[a]	0.002	0.1		
GMA3[a]	− 0.003	− 0.3		
AR(1)	0.552	5.0	0.497	4.6
AR(2)	0.455	4.1		
σ^{m}	0.073	11.1		
Log-Likelihood	69.9			
Adjusted R^2			0.92	
Durbin-Watson	2.4		1.86	

[a]*GMA* and *GFA* are specified as a second-order polynomial distributed lag function of the previous four quarters' advertising expenditures. End-point restrictions are imposed for *GFA* (in the OLS fluid equation) but not for *GMA* (in the tobit manufactured equation).

The coefficients of interest to this study are the ones associated with the average industry conduct parameters in equation (23). As mentioned, the relationship between $(1-\Phi)$ and λ^k is expected to be negative because individual dairy processors, in an attempt to capture a larger share of the boom market, may be inclined to behave more competitively in the market equilibrium regime. This hypothesis is not rejected by the empirical results, as the estimated coefficients for fluid and manufactured milk markets are negative and statistically significant at the 1% level. The implications of this result are rather interesting. If the government continues to deregulate the dairy price support program in the future, then the probability of a market equilibrium regime occurring will increase over time. Since λ^k and $(1-\Phi)$ are negatively related, the result implies that deregulation will have a pro-competitive effect on the market conduct of fluid and manufactured processors.

To gain insight on the magnitude of market power in both markets, the conjectural elasticities for manufactured and fluid processors are computed from (23), using the

Table 3. Estimated Manufactured and Fluid Processor First-Order Conditions

Variable		Estimated Coefficient	t-Value
Manufactured First-Order Condition:			
PPIFE	(β^m_{ii})	−0.222	−1.4
$(PPIFE*WAGE)^{1/2}$	(β^m_{ij})	0.704	1.4
WAGE	(β^m_{jj})	−2.117	−1.4
Intercept	(γ^m)	3.330	14.8
$1-\Phi$	(δ^m)	−2.660	−10.9
AR(1)		0.609	6.2
Adjusted $R^2 = 0.91$			
Durbin-Watson = 1.9			
Fluid First-Order Condition:			
PPIFE	(β^f_{ii})	0.318	59.3
$(PPIFE*WAGE)^{1/2}$	(β^f_{ij})	−1.002	−64.3
WAGE	(β^f_{jj})	4.655	77.8
Intercept	(γ^f)	1.778	26.5
$1-\Phi$	(δ^f)	−0.630	−22.4
AR(1)		0.647	6.9
Adjusted $R^2 = 0.88$			
Durbin-Watson = 2.1			

Note: The system of first-order conditions is estimated by the seemingly unrelated regression procedure.

estimates of γ and δ. Table 4 presents the simulated conjectural elasticities and their t-ratios over the period of 1976–92.[10] For most periods of the sample, the conjectural elasticities of manufactured processors are found to be smaller than those of fluid processors; the mean values of λ^m and λ^f are 0.100 and 0.176, respectively. The finding that fluid processors behave in a less competitive manner than manufactured processors is intuitive because markets for fluid milk are less national in scope due to the perishability and relatively high transportation costs of the product. While the average industry conduct parameters of manufactured and fluid processors are statistically different from zero for all the quarters, the magnitudes of these parameters are not alarming, as they are still closer to zero (perfect competition) than one (monopoly). Furthermore, both parameters do not exhibit a strong pattern of increasing over time; a finding which is reassuring given that the industry has become more concentrated over the sample period.

[10]The variances of the simulated conjectural elasticities are obtained through bootstrapping.

Table 4. Simulated Manufactured and Fluid Conjectural Elasticities

Year	Quarter	λ^m	t-Value	λ^f	t-Value	Year	Quarter	λ^m	t-Value	λ^f	t-Value
1976	I	0.092	11.3	0.178	21.7	1985	I	0.080	9.7	0.172	21.0
	II	0.172	21.5	0.204	25.5		II	0.056	6.8	0.160	19.5
	III	0.080	9.8	0.173	21.1		III	0.059	7.2	0.162	19.7
	IV	0.153	19.0	0.198	24.7		IV	0.071	8.7	0.168	20.5
1977	I	0.101	12.4	0.181	22.2	1986	I	0.139	17.2	0.194	24.1
	II	0.096	11.7	0.179	21.9		II	0.071	8.7	0.168	20.5
	III	0.050	6.1	0.156	19.1		III	0.102	12.5	0.182	22.3
	IV	0.057	6.9	0.160	19.5		IV	0.062	7.6	0.163	19.9
1978	I	0.045	5.5	0.152	18.6	1987	I	0.156	19.4	0.199	24.8
	II	0.072	8.7	0.168	20.5		II	0.121	14.8	0.188	23.2
	III	0.041	5.1	0.150	18.4		III	0.064	7.8	0.165	20.1
	IV	0.078	9.5	0.172	20.9		IV	0.075	9.2	0.170	20.8
1979	I	0.103	12.7	0.182	22.3	1988	I	0.108	13.3	0.184	22.6
	II	0.154	19.1	0.199	24.7		II	0.062	7.5	0.163	19.9
	III	0.053	6.5	0.158	19.3		III	0.058	7.0	0.161	19.6
	IV	0.186	23.4	0.208	26.1		IV	0.043	5.2	0.151	18.5
1980	I	0.313	41.1	0.236	31.0	1989	I	0.090	11.0	0.177	21.6
	II	0.249	32.0	0.223	28.6		II	0.092	11.3	0.178	21.7
	III	0.207	26.2	0.213	26.9		III	0.050	6.0	0.156	19.0
	IV	0.249	32.0	0.223	28.6		IV	0.053	6.5	0.158	19.3
1981	I	0.224	28.5	0.217	27.6	1990	I	0.047	5.7	0.154	18.8
	II	0.148	18.4	0.197	24.5		II	0.036	4.4	0.145	17.8
	III	0.128	15.8	0.191	23.5		III	0.036	4.4	0.145	17.8
	IV	0.149	18.4	0.197	24.5		IV	0.046	5.6	0.153	18.7
1982	I	0.207	26.2	0.213	26.9	1991	I	0.037	4.6	0.147	18.0
	II	0.135	16.7	0.193	23.9		II	0.035	4.3	0.145	17.8
	III	0.119	14.6	0.188	23.1		III	0.052	6.3	0.157	19.2
	IV	0.137	17.0	0.194	24.0		IV	0.040	5.0	0.149	18.3
1983	I	0.143	17.8	0.196	24.3	1992	I	0.084	10.2	0.174	21.3
	II	0.150	18.6	0.198	24.5		II	0.036	4.5	0.146	17.9
	III	0.164	20.4	0.202	25.2		III	0.061	7.4	0.163	19.8
	IV	0.072	8.8	0.169	20.6		IV	0.035	4.3	0.145	17.8
1984	I	0.110	13.6	0.185	22.7						
	II	0.086	10.5	0.175	21.4						
	III	0.050	6.1	0.156	19.0	**Mean**		**0.100**		**0.176**	
	IV	0.063	7.7	0.164	20.0						

Summary

Bridging the market conduct and switching regime literatures, this article presents a framework to estimate the market power of an oligopolistic industry where there is a government price support program impacting firms' output price. The proposed framework was then used to estimate the degree of market power exercised by manufactured and fluid processors in the U.S. dairy industry. The study also examined whether government price intervention in the dairy industry has a pro-competitive or anti-competitive influence on market conducts.

The results indicated that the average industry conduct parameters of manufactured and fluid processors were statistically different from zero (perfect competition) for all quarters during the period of 1976–92. However, the magnitudes of these estimated parameters were found not be alarming as they are still closer to zero than one (monopoly). The results also indicated that manufactured and fluid processors tend to behave in a more competitive manner in the market equilibrium regime than in the government supported regime. This result suggests that further deregulation of the dairy price support program will have a pro-competitive impact on market conduct.

Though the oligopolistic switching regime estimation framework was specifically applied to the dairy processing industry, it can also be employed to a farm-level problem. For example, the procedure can be invoked to examine the selling power of a group of big farmers whose output price is under the control of a government price support program. Further, the framework can be modified to derive a procedure for estimating the buying power of processors (e.g., flour processors buying wheat) and big farmers (e.g., large hog and poultry producers buying corn) whose input price is the subject of government price interventions.

[*Received October 1994; final version received September 1995.*]

References

Appelbaum, E. "The Estimation of the Degree of Oligopoly Power." *J. Econometrics* 19(1982):287–99.

Azzam, A., and E. Pagoulatos. "Testing for Oligopolistic and Oligopsonistic Behavior: An Application to the U.S. Meat-Packing Industry." *J. Agr. Econ.* 41(1990):362–70.

Azzam, A., and T. Park. "Testing for Switching Market Conduct." *Appl. Econ.* 25(1993):795–800.

Buschena, D. E., and J. M. Perloff. "The Creation of Dominant Firm Market Power in the Coconut Oil Export Market." *Amer. J. Agr. Econ.* 73(1991):1000–8.

Cornick, J., and T. L. Cox. "Endogenous Switching Systems: Issues, Options, and Application to the U.S. Dairy Sector." *J. Agr. Econ. Res.* 44(1994):28–38.

Durham, C. A., and R. J. Sexton. "Oligopsony Potential in Agriculture: Residual Supply Estimation in California's Processing Tomato Market." *Amer. J. Agr. Econ.* 74(1992):962–72.

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. (LNA). *AD $ Summary.* New York. Selected issues.]

Lee, L. F. "Simultaneous Equations Models with Discrete and Censored Dependent Variables." In *Structural Analysis of Discrete Data with Econometric Applications*, eds., C. F. Manski and D. McFadden, pp. 346–64. Cambridge: The MIT Press, 1990.

Liu, D. J., H. M. Kaiser, T. D. Mount, and O. D. Forker. "Modeling the U.S. Dairy Sector with Government Intervention." *West. J. Agr. Econ.* 16(1991):360–73.

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

Rotemberg, J. J., and G. Saloner, "A Supergame-Theoretic Model of Price Wars During Booms." *Amer. Econ. Rev.* 76(1986):390–407.

Schroeter, J. R. "Estimating the Degree of Market Power in the Beef Packing Industry." *Rev. Econ. and Statis.* 70(1988):158–62.

Schroeter, J. R., and A. Azzam. "Measuring Market Power in Multi-Product Oligopolies: The U.S. Meat Industry." *Appl. Econ.* 22(1990):1365–376.

———. "Marketing Margins, Market Power, and Price Uncertainty." *Amer. J. Agr. Econ.* 73(1991):990–99.

Shonkwiler, J. S., and G. S. Maddala. "Modeling Expectations with Bounded Prices: An Application to the Market of Corn." *Rev. Econ. and Statis.* 67(1985):697–02.

Snedecor, G. W., and W. G. Cochran. *Statistical Methods.* Ames IA: The Iowa State University Press, 1980.

Suzuki, N., H. M. Kaiser, J. E. Lenz, and O. D. Forker. "An Analysis of U.S. Dairy Policy Deregulation Using an Imperfect Competition Model." *Agr. and Resour. Econ. Rev.* 23(1994):84–93.

Wann, J. J., and R. J. Sexton. "Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing." *Amer. J. Agr. Econ.* 74(1992):980–90.

U.S. Department of Agriculture, Agricultural Marketing Service. *Federal Milk Order Market Statistics.* USDA/FMOM, Washington DC. Selected issues, 1975–90.

———. Economic Research Service. *Dairy Situation and Outlook.* USDA/ERS, Washington DC. Selected issues, 1975–90.

U.S. Department of Labor, Bureau of the Census. *Concentration Ratios in Manufacturing.* Washington DC. Selected issues.

———. Bureau of Labor Statistics. *Consumer Price Index.* USDA/CPI, Washington DC. Selected issues, 1975–90.

———. *Employment and Earnings.* USDA/EE, Washington DC. Selected issues, 1975–90.