An Analysis of U.S. Dairy Policy Deregulation using an Imperfect Competition Model

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An imperfect competition model of the U.S. milk market is developed for analyzing the impacts of dairy policy deregulation. Estimated degree-of-competition parameters indicate that the U.S. milk market has become more competitive over time. The usefulness of the model is demonstrated by showing the relative differences of dynamic simulation results of the imperfect competition model with the results of a conventional exogenous fluid differential model.

Since the General Agreement on Tariffs and Trade (GATT) reached a successful agreement in December, 1993, it is useful for the U.S. dairy industry to be pro-active and consider the impact of deregulation of the U.S. dairy industry. There are three main federal programs that form the basis of U.S. dairy policy and will be affected by trade liberalization: the dairy price support program, federal milk marketing orders, and import quotas. There is also domestic pressures that bring the various programs into question, e.g., regional concerns over federal milk marketing orders, and budgetary pressure on the dairy price support program.

Most previous dairy policy models (e.g., Kaiser, Streeter, and Liu; Liu et al.) have assumed an exogenous fluid differential because the dairy industry is regulated by federal milk marketing orders which obligate milk handlers to pay the minimum Class I (fluid) differential.[1] However, the fluid differential is actually not exogenous because, in addition to the premiums associated with the federal minimum prices, there are over-order payments resulting from negotiations[2] between dairy cooperatives and processors (or manufacturers).[3] Most previous models have not accounted for over-order payments. An imperfect competition model with an endogenous fluid price differential is necessary for estimating how large the fluid price differential might be without existing regulations.

While imperfect competition models of the Japanese milk market have been developed by Suzuki, Lenz, and Forker; and Suzuki et al., there have been no imperfect competition models developed for the U.S. milk market.[4] The purpose of this paper is to present an imperfect competition model with an endogenous fluid price differential to evaluate the market effects of deregulating the U.S. dairy industry. The usefulness of the model is demonstrated by comparing the results of dynamic

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[1] Federal marketing orders also set the minimum Class II and Class III prices. The M-W price has been used as the minimum Class III price for most orders since 1960. The M-W price is an estimate of the average price paid for manufacturing grade (Grade B) milk by manufacturing plants in Minnesota and Wisconsin. Grade B milk is now a very small portion of the national market (approximately 6%), although it is still used to set M-W prices.

[2] The Capper-Volstead Act accords cooperatives special treatment for their collective bargaining.

[3] In this paper, the term "processor" refers to processor of fluid milk, while the term "manufacturer" refers to manufacturer of non-fluid dairy products.

[4] The American Agricultural Economics Association Task Force Report stated in 1986 that "since the 1930's, agricultural economists have emphasized that some model besides pure competition is needed. But no one has yet proposed such a model in a form capable of generating comparative-static results concerning the effects of marketing orders as compared to no orders." (p. 34)

simulations of this model with the results of a conventional exogenous fluid differential model.

In this study we estimate the effective fluid price (the M-W price + the minimum fluid price differential + any over-order payment) to measure the degree of competition in the U.S. milk market, and incorporate a degree-of-competition measure into the U.S. dairy policy model. The degree-of-competition measure based on the effective fluid price differential (the minimum fluid price differential + any over-order payment) is considered an aggregate indicator of the degree of imperfection created by federal policies, and market power of cooperatives and processors and manufacturers in the U.S. milk market. While over-order payments exist not only for Class I milk, but also for Class II and III milk, over-order payments for Class II and III milk are all included in the fluid differential in this analysis because of data limitation.

Theoretical Model

To measure the degree of imperfection, a perfectly competitive market is defined as a basis of comparison. One would expect a relatively uniform manufacturing milk price nationwide. According to Robinson,

> "Class II or manufacturing milk prices are approximately the same in all markets and are linked to the M-W price. Uniform pricing of manufacturing milk is necessary because products derived from surplus milk are easily transported between regions. Cheese, butter, and skim-milk powder produced in federal-order markets must compete with similar products manufactured from grade B milk in Minnesota and Wisconsin. Handlers operating in federal-order markets will not purchase surplus milk if it is priced higher than what unregulated plants pay for manufacturing milk in the Midwest." (Robinson, p. 116)

Without cooperative market power and revenue pooling, individual farmers would compete with each other until the price difference between fluid and manufacturing milk would disappear except for modest locational differences. If a market did not have enough milk to meet local fluid uses, there would be some locational or transportation differentials paid for fluid milk even without marketing orders and cooperatives because fluid plants would have to transport milk from further distances. Fluid plants tend to be located near population centers, while manufacturing plants tend to be located near farms because dairy products are less bulky to ship than raw or fluid milk.

We do not consider such possibilities in the current analysis because the number of deficit areas and the magnitude of fluid differentials in a perfectly competitive market is difficult to predict.[5] Several previous studies, which tried to estimate welfare losses caused by marketing orders, also assumed no differentials as a benchmark for comparison (Buxton; Dahlgran; Ippolito and Masson; Masson and Eisenstat).

If one specifies that, under imperfect competition, the role of dairy cooperatives is to allocate their raw milk supply to fluid and manufacturing markets so as to maximize total milk sales revenues, the first order condition is to equate marginal revenues from fluid and manufacturing milk. When cooperatives undertake processing themselves, manufacturing costs should be taken into account. For simplicity, our current model does not incorporate these costs. Under perfect competition, the first order condition is expressed as:

$$(1) \qquad P_f = P_m$$

where P_f is fluid milk price, P_m is manufacturing milk price.

At the opposite extreme, the first order condition for monopoly or collusion is:

$$(2) \qquad P_f(1 - 1/\epsilon_f) = P_m(1 - 1/\epsilon_m)$$

where $\epsilon_f = |(\partial Q_f/\partial P_f) \cdot (P_f/Q_f)|$ and $\epsilon_m = |(\partial Q_m/\partial P_m) \cdot (P_m/Q_m)|$ are price elasticities of fluid and manufacturing milk demand in absolute value terms; Q_f is the aggregate quantity of fluid milk demand; and Q_m is the aggregate quantity of manufacturing milk demand.

To express an intermediate degree of imperfect competition, a degree-of-competition parameter, θ $(0 \leq \theta \leq 1)$, is introduced. Then, equality across markets of "perceived" marginal revenue is expressed as:

$$(3) \qquad P_f(1 - \theta_f/\epsilon_f) = P_m(1 - \theta_m/\epsilon_m)$$

or

$$(4) \qquad P_f + \theta_f \cdot Q_f/(\partial Q_f/\partial P_f) = P_m + \theta_m \cdot Q_m/(\partial Q_m/\partial P_m).$$

The parameter θ is considered an aggregate indicator of the degree of competition in the milk market. Marginal milk production costs do not enter

[5] McDowell, Fleming, and Spinelli looked at differentials that would be obtained in different markets under a multiple base point pricing system.

equation (3) or (4) because milk production is almost never controlled by cooperatives, but rather it is determined by individual farmers' response to blend prices they receive.

Although the degree of competition parameter is specified by cooperatives' revenue maximizing behavior, it is also affected by the countervailing power of processors and manufacturers. Therefore, it should be noted that the degree-of-competition parameter reflects both cooperatives' and processors' and manufacturers' market power. We do not have a way to explicitly incorporate processor's and manufacturers' oligopsonistic power into the current model.

If θ can be assumed to be the same for both fluid and manufacturing markets, one can identify a value of θ which satisfies equation (3) or (4), with values of milk price elasticities estimated by demand functions and observations of P_f, P_m, Q_f, and Q_m. However, θ_m will probably be lower than θ_f because cooperatives face more competition in the manufacturing milk market than in the fluid milk market. Fluid milk products are costlier to transport than manufactured milk products, and, therefore, the geographical scope of markets for manufactured milk products in general will exceed that for fluid milk products. Since there likely is more competition in the manufactured product market than in the fluid market, the manufacturing milk market is probably more competitive.

Instead of deriving θ with the assumption that $\theta_f = \theta_m$ by estimating both fluid and manufacturing demand equations, one could estimate the fluid (or manufacturing) demand equation and equation (3) or (4) into which the manufacturing (or fluid) demand equation is substituted. The parameter, θ, is directly estimated as a coefficient of (3) or (4) using this method (Bresnahan), and θ_f and θ_m can be separately identified. However, the coefficients for the manufacturing (or fluid) demand equation cannot be identified (See Appendix).

The solution to this problem adopted here is to assume that $\theta_m = 0$ and then solve for θ_f. The assumption that $\theta_m = 0$ is plausible because the manufacturing milk price for each market is given as the M-W price, and the M-W price is indirectly supported by government purchases of dairy products. We do not consider the fact that some orders such as Chicago obtain significant over-order Class III payments (Babb) in this analysis because we have no national average data on over-order payments for Class III milk. We use the assumption ($\theta_m = 0$) and identify a value of θ_f which satisfies (3) or (4), assuming that θ_f is constant in each time period and that cooperatives approximately realize the condition expressed by (3) or (4). This means that (3) and (4) can be replaced with:

(5) $$P_f(1 - \theta_f/\epsilon_f) = P_m$$

or

(6) $$P_f + \theta_f \cdot Q_f/(\partial Q_f/\partial P_f) = P_m$$

The full imperfect competition model is expressed as:

Milk production:

(7) $$Q = f(BP)$$

Fluid milk demand:

(8) $$Q_f = g(P_f)$$

Manufacturing milk demand:

(9) $$Q_m = h(P_m)$$

Milk sales maximizing allocation:

(10) $$P_f + \theta_f \cdot Q_f/(\partial Q_f/\partial P_f) = P_m$$

Milk uses identity:

(11) $$Q \equiv Q_f + Q_m + FUSE$$

Blend price:

(12) $$BP = (P_f \cdot Q_f + P_m \cdot Q_m)/(Q - FUSE)$$

where Q is aggregate milk production, BP is the blend price, and FUSE is on-farm use of milk produced (assumed to be exogenous), with all other variables as previously defined. The other exogenous variables (feed price, income, advertising expenditures, and trend) are not included in the above simplified expressions. With six endogenous variables (Q, Q_f, Q_m, P_f, P_m, BP) and six equations, the model is complete. Because this model expresses farmers' supply, and processors' and manufacturers' demand for raw milk, government purchases of dairy products and changes in commercial inventories are not treated separately, i.e., manufacturing milk demand (Q_m) includes commercial manufacturing demand, government purchases of dairy products, and changes in commercial inventories on a milk-equivalent basis.

Empirical Model Estimation[6]

Over-Order Payment Data

The effective fluid milk price is equal to the M-W price plus the minimum Class I differential plus

[6] The data and its sources are listed in Kaiser et al.

any over-order payments. Since the only available data on over-order payments pertain to "announced" over-order payments in 35 markets by the USDA, it is difficult to collect the over-order payment data for all cooperatives over time and to construct a national average time-series data set. Instead, the effective fluid milk price (P_f) is estimated by solving the blend price equation for P_f:

$$(13)\ P_f = [BP \cdot (Q - FUSE) - P_m \cdot Q_m)]/Q_f$$

The difference between the Class II and III prices is minor and neglected like most previous models. However, since over-order payments exist not only for Class I milk, but also for Class II and III milk, equation (13) assigns the over-order payments for Class II and III milk to the fluid differential. Consequently, the estimated effective fluid prices may be higher than the actual ones because they include all premiums over the M-W price. To check the possible bias of using the estimates from equation (13), the estimated prices are compared with simple annual average values of "announced" cooperative Class I prices in 35 markets reported by the USDA. As shown in table 1, the estimated effective prices are larger than the cooperative prices in many years as is expected, but the differences are relatively small, and in some recent years the announced cooperative prices are slightly higher.

Table 1. Differences Between the Effective Fluid Milk Prices Estimated by Equation (13) and the "Announced" Cooperative Class I Prices Reported by the USDA (Simple Annual Average)

	Effective Fluid Milk (Class I) Price		
Year	Estimates by Equation (13) (A)	"Announced" Cooperative Prices in 35 Markets (B)	Difference (A)–(B)
	$/cwt	$/cwt	$/cwt
1976	11.13	10.91	+0.22
1977	11.17	10.81	+0.36
1978	11.89	11.61	+0.28
1979	13.52	13.25	+0.27
1980	14.75	14.26	+0.49
1981	15.62	15.22	+0.40
1982	15.45	15.09	+0.36
1983	15.45	15.12	+0.33
1984	15.22	14.88	+0.34
1985	14.85	14.89	−0.04
1986	14.51	14.52	−0.01
1987	14.67	14.52	+0.15
1988	14.10	14.22	−0.12
1989	15.24	15.37	−0.13
1990	16.03	16.41	−0.38

This comparison implies that over-order premiums for Class II and III milk are not large on average, and, therefore, the effective fluid prices estimated by equation (13) probably does not generate a serious bias in estimating the degree-of-competition parameter.

The blend price is the all milk price reported by the USDA which includes over-order payments. The differences between the estimated effective fluid milk price and the minimum Class I price are shown in Figure 1. The effective prices are higher than the minimum prices in almost all years, indicating the existence of over-order payments. Figure 1 implies that most previous models had internal data inconsistency because they used the minimum Class I price and the all milk price.

Supply Function

The aggregate milk supply (Q) is estimated using quarterly data from 1975 through 1990 as a function of the current and lagged milk-feed price ratio (MF = blend price/feed price), time trend ($TREND$) representing technical progress, intercept dummy variables for the Milk Diversion Program (MDP) and the Dairy Termination Program (DTP), and harmonic seasonality variables ($SIN1$, $COS1$, and $COS2$) (see table 3). The econometric results are presented in table 2, along with all of the estimated equations.

A polynomial distributed lag is imposed to account for lagged effects of the milk-feed price ratio.[7] Among many alternative forms, the second degree polynomial distributed lag with both endpoints constrained to lie close to zero and a six quarter lag provided the best results. This lag length seems reasonable considering the biological reproduction cycle of dairy cows.

The estimated long run price elasticity of milk supply is 0.224, which is similar to Chavas and Klemme's estimated two-year price elasticity of 0.20, and Weersink's estimate of 0.29. To overcome significant first-order autocorrelation in the disturbance term, the Cochrance-Orcutt procedure is employed. Two-Stage-Least-Squares ($TSLS$) estimation was used because both milk production and the blend price are endogenous variables in the model.

[7] Because long run milk-feed price effects are considered by imposing a polynomial distributed lag, the number of cows is not included as an explanatory variable.

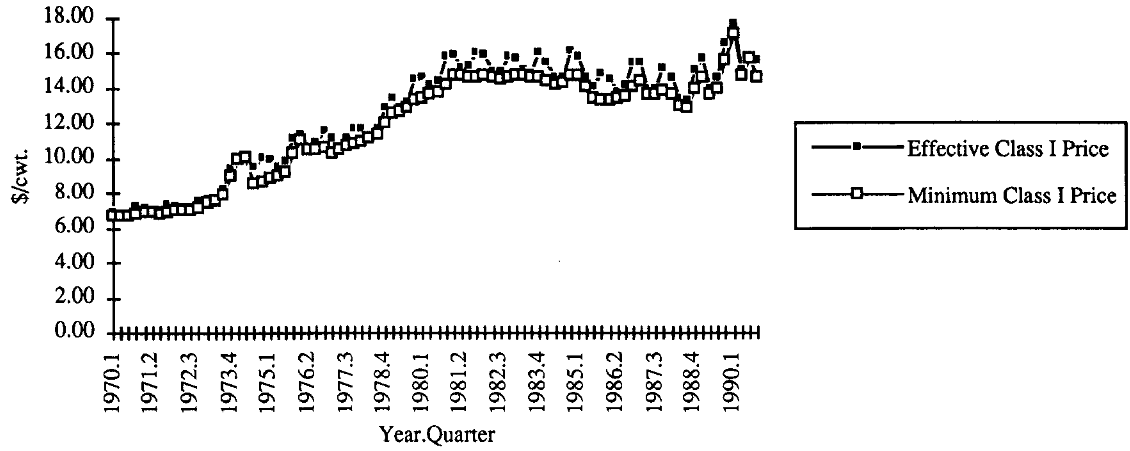

Figure 1. Quarterly Effective and Minimum Class I Prices in the U.S., 1970–90.

Fluid Milk Demand Function

The fluid milk demand function is the processors' "derived" demand for raw milk.[8] To insure that all identities are meaningful, all quantities in the model are measured on a milk-fat equivalent basis. Per capita fluid milk demand (Q_f/N) is explained by the effective fluid milk price (P_f), per capita income (*INC*), the ratio of persons under 19 years old to the total population (*AU19*), current and lagged fluid advertising expenditures (branded fluid advertising – BA_f, and generic fluid advertising – GA_f), and harmonic seasonality variables (*SIN1*, *COS1*, and *COS2*). The variables P_f and *INC* are deflated by the consumer price index, and BA_f and GA_f are deflated by the media price index.

A polynomial distributed lag is imposed to account for lagged generic fluid advertising effects. The second degree polynomial distributed lag with both endpoints constrained to lie close to zero and a five quarter lag provided the best results. The effects are largest four to six months later, and erode in about a year. No lagged effects of branded fluid advertising were found to be significant, but the current effect was significant.

Calculated at mean data points, the estimated elasticities of fluid demand with respect to price, income, and branded fluid advertising are −0.293, 0.483, and 0.0089, respectively. Liu et al.'s estimated elasticities of retail fluid demand with respect to price and income were −0.282 and 0.154, respectively. The estimated long run generic advertising elasticity is 0.054, which is similar to Kinnucan and Forker's estimate of 0.051 in New York City, but larger than Liu et al.'s estimate of 0.0175 for retail-level national fluid demand.

The fluid demand function was estimated using a linear form because other functional forms (double-log, semi-log, log-inverse, and inverse) resulted in negative marginal revenue estimates and were rejected because negative fluid milk marginal revenue precludes discussion of the collusion case expressed by equation (2).[9] TSLS was used to estimate this equation because both quantity and price are endogenous in the model.

Manufacturing Milk Demand Function

Because this is the manufacturers' "derived" demand for raw milk, government purchases of dairy products and changes in commercial inventories are not treated separately. Per capita manufacturing milk demand (Q_m/N) was estimated as a function of the manufacturing milk price (P_m) deflated by the *CPI*, per capita income (*INC*) deflated by the *CPI*, the ratio of persons under 19 years old to the total population (*AU19*), current and lagged manufacturing milk advertising expenditures (branded manufactured product – BA_m, and generic manufactured product – GA_m), intercept dummy variables for the *DTP* and *MDP*, and harmonic seasonality variables (*SIN1*, *COS1*, and *COS2*).

The *DTP* and *MDP* were included in this de-

[8] It is assumed that changes in retail fluid and manufactured product prices correspond to changes in raw milk prices.

[9] The manufacturing demand function is also estimated using a linear form to be consistent with the fluid demand function.

Table 2. The Estimated Equations

Milk Supply (1975.2 − 90.4)

$ln(Q) =$ 3.899 + 0.019 $ln(MF)$ + 0.032 $ln(MF)_{-1}$ + 0.040 $ln(MF)_{-2}$
(24.75)[a] (3.86) (3.86) (3.86)
+ 0.043 $ln(MF)_{-3}$ + 0.040 $ln(MF)_{-4}$ + 0.032 $ln(MF)_{-5}$
(3.86) (3.86) (3.86)
+ 0.019 $ln(MF)_{-6}$ + 0.0039 *TREND* − 0.024 *MDP* − 0.041 *DTP*
(3.86) (8.17) (−1.67) (−2.94)
− 0.0053 *SIN1* − 0.052 *COS1* + 0.0071 *COS2* + 0.734 $(U^{Q})_{-1}$
(− 1.94) (− 19.57) (5.40) (7.57)
Adj. R^2 = 0.95 D.W. = 1.79

Fluid Demand (1976.3 − 90.4)

$Q_f/N =$ − 0.077 − 0.105 (P_f/CPI) + 0.0011 (INC/CPI)
(− 2.49) (− 3.16) (2.70)
+ 1.0 × 10^{-7} (GA_f) + 1.7 × 10^{-7} $(GA_f)_{-1}$ + 2.0 × 10^{-7} $(GA_f)_{-2}$
(3.10) (3.10) (3.10)
+ 2.0 × 10^{-7} $(GA_f)_{-3}$ + 1.7 × 10^{-7} $(GA_f)_{-4}$ + 1.0 × 10^{-7} $(GA_f)_{-5}$
(3.10) (3.10) (3.10)
+ 6.8 × 10^{-7} (BA_f) + 0.387 *AU19* + 0.0016 *SIN1* + 0.0023 *COS1*
(2.60) (4.85) (8.28) (10.15)
+ 0.00018 *COS2* + 0.788 $(U^{Qf/N})_{-1}$
(3.70) (4.94)
Adj. R^2 = 0.92 D.W. = 2.02

Manufacturing Demand (1976.3 − 90.4)

$Q_m/N =$ 0.378 − 1.113 (P_m/CPI) − 0.0069 (INC/CPI)
(4.66) (−3.96) (−3.55)
+ 3.6 × 10^{-7} (BA_m) + 5.4 × 10^{-7} $(BA_m)_{-1}$ + 5.4 × 10^{-7} $(BA_m)_{-2}$
(2.34) (2.34) (2.34)
+ 3.6 × 10^{-7} $(BA_m)_{-3}$ − 0.0059 *DTP* + 0.018 *D*89.4
(2.34) (−1.71) (2.80)
− 0.022 *D*90.4 − 0.0013 *SIN1* − 0.0074 *COS1* + 0.00074 *COS2*
(−3.16) (−1.98) (−9.08) (2.12)
+ 0.670 $(U^{Qm/N})_{-1}$
(3.78)
Adj. R^2 = 0.78 D.W. = 1.74

[a]Figures in parentheses are *t*-values.

mand function because this derived demand includes government purchases of dairy products as well as commercial use. Since these two programs significantly affected the government component of manufacturer demand, they are included in this equation. The federal dairy price support program is considered in this equation in that the manufacturing milk price (P_m = M-W price) is indirectly supported through government purchases of dairy products. Intercept dummy variables are also included for the fourth quarters of 1989 and 1990 because regression residuals for both periods are very large. The outlier for the fourth quarter of 1989 is likely due to the unusually strong demand for nonfat dry milk during that quarter, but we have no explanation for the fourth quarter 1990 outlier.[10]

A polynomial distributed lag is imposed to account for lagged branded manufacturing advertising effects. The second degree polynomial distributed lag with both endpoints constrained to lie close to zero and a three quarter lag provided the best results. We could not estimate any significant effects of generic manufacturing advertising (a negative coefficient with very small t-value is found). The variable, *AU19*, and the intercept dummy variable for the *MDP* were also not significant. Consequently, these variables were dropped from the model. The estimated coefficient on the income variable is negative and significant, which is not consistent with expectations. Because each dairy product has a very different demand trend and structure, disaggregated estimation would likely produce better results, however, this is beyond the scope of the present analysis.

Calculated at mean data points, the estimated elasticities of manufacturing demand with respect to price and long run branded advertising are −1.575 and 0.234, respectively. The estimated price elasticity is relatively large compared to previous studies such as −0.928 by Liu et al. Again, TSLS was used to estimate this equation because

[10] Inventory building by cheese wholesalers and manufacturers in the face of uncertainties in milk supply could be another factor to explain unprecedented increases in M-W prices.

Table 3. Definitions for the Variables Used in the Equations Presented in Table 2

Q	=	milk production (billion pounds),
MF	=	(blend price)/(feed price), where blend price is all milk price ($/cwt) and feed price is U.S. average price of 16% protein dairy feed ($/ton),
$TREND$	=	time trend variable equal to 1 for quarter 1, 1970, . . . ,
MDP	=	intercept dummy variable for the Milk Diversion Program equal to 1 for quarter 1, 1984 through quarter 2, 1985, 0 otherwise,
DTP	=	intercept dummy variable for the Dairy Termination Program equal to 1 for quarter 2, 1986 through quarter 3, 1987, 0 otherwise,
$SIN1$, $COS1$, and $COS2$	=	harmonic seasonality variables representing the first wave of the sine function (1, 0, −1, 0), the first wave of the cosine function (0, −1, 0, 1), and the second wave of the cosine function (−1, 1, −1, 1), respectively. (1, 0, −1, 0) etc. are values for each quarter, where the first quarter means $\pi/2$, second π, third $3\pi/2$, and fourth 2π,
U_{-1}	=	lagged residual,
Q_f	=	fluid milk marketed (billion pounds),
N	=	U.S. population (million persons),
P_f	=	effective Class I price estimated using equation (13) ($/cwt),
CPI	=	consumer price index for all items (1982–84 = 100),
INC	=	disposable personal income per capita ($1,000),
GA_f and BA_f	=	generic and branded fluid advertising expenditures deflated by the media price index ($1,000), respectively,
$AU19$	=	ratio of persons under 19 years old to the total population (total = 1),
Q_m	=	manufacturing milk marketed (billion pounds),
P_m	=	M-W price ($/cwt),
BA_m	=	branded manufacturing advertising expenditures (including branded butter advertising, branded ice cream advertising, and branded cheese advertising) deflated by the media price index ($1,000),
$D89.4$	=	intercept dummy variable equal to 1 for quarter 4, 1989, 0 otherwise,
$D90.4$	=	intercept dummy variable equal to 1 for quarter 4, 1990, 0 otherwise.

both manufacturing demand and price are endogenous in the model.

Degree-of-Competition Parameter

The degree-of-competition parameter is equal to one under monopoly or collusion, and zero under perfect competition or price-taking behavior. As shown in table 4, derived annual average estimates of θ_f's using equation (5) or (6) indicate that the U.S. milk market is neither perfectly competitive nor purely monopolistic. The estimates imply some degree of market imperfection that has been declining over time.

Table 4. Estimated Degree-of-Competition Parameters (Annual Average)

Year	Degree-of-Competition Parameter (θ_f)
1977	0.077 (0.024)[a]
1978	0.065 (0.021)
1979	0.066 (0.021)
1980	0.066 (0.021)
1981	0.065 (0.020)
1982	0.061 (0.019)
1983	0.059 (0.019)
1984	0.056 (0.018)
1985	0.061 (0.019)
1986	0.057 (0.018)
1987	0.058 (0.018)
1988	0.050 (0.016)
1989	0.044 (0.014)
1990	0.055 (0.017)

[a]Figures in parentheses are standard errors defined by: $((P_f - P_m)/CPI)/(Q_f/N)$ · [standard error of the fluid demand function's estimated slope].

Competitive pressures in the fluid market have increased over time due to improvements in transportation technology and increasing reserves of milk in areas other than the Minnesota and Wisconsin. Dairy farmers have tried to reduce the competitive pressures by merging cooperatives and milk marketing orders while size of manufacturing plants have become larger. The gradually decreasing degree-of-competition parameters could be the consequences of a power balance caused by these developments.

Simulations

To determine the validity of the estimated model for analyses of deregulation, values for the endogenous variables, given the values for the exogenous variables, were determined in a fully dynamic simulation by the Gauss-Seidel technique[11] for the historical period 1980–90. As illustrated by the

[11] This is a numerical technique used in the TSP-Micro econometric software. It is similar to the Newton and the Fletcher-Powell methods, but is more powerful in dealing with large models that have block components.

Table 5. Mean Absolute Percent Errors (1980.1–90.4)

Endogenous Variables	Mean Absolute Percent Error
	%
Fluid Milk Price (P_f)	3.10
Manufacturing Milk Price (P_m)	3.70
Blend Price (BP)	3.54
Fluid Milk Demand (Q_f)	1.60
Manufacturing Milk Demand (Q_m)	2.91
Milk Production (Q)	1.67

mean absolute percent errors[12] shown in table 5, the largest error is less than 4%, which is quite reasonable for a dynamic simulation.

It is unclear how deregulation might be implemented. Because our focal point is to examine the relative differences between model results, we do not consider any gradual deregulation following some time schedule.

For simulating cases without import quotas where the manufacturing milk market is open to foreign imports, the manufacturing milk price (P_m) in equation (10) is interpreted as a given imported product price measured on a milk-fat equivalent basis. It is assumed that farmers would consider the demand for manufacturing milk to be perfectly elastic at the import product (world) price. Because the model is a single-country model, we cannot determine the import product price level after elimination of import quotas endogenously by solving a multi-country model such as the Ministerial Trade Mandate (MTM) model of the Organization for Economic Cooperation and Development (OECD), and USDA's SWOPSIM (OECD; Roningen). Because our focal point is to examine the differences between two model results, we assume a 20% decline from the current P_m level for each year as an example.

In addition, Q_m is replaced by Q_{Mi} (total manufacturing milk demand including dairy imports in milk equivalents) in (9), i.e.:

$$(14) \qquad Q_{Mi} = h(P_m)$$

Also, the following definitional identity for imports is added:

$$(15) \qquad Q_I \equiv Q_{Mi} - Q_m$$

where Q_I is dairy imports on a milk-fat equivalent basis.

[12] The formula is $(1/n)\Sigma|(P - A)/A| \times 100$, where P is the predicted value and A is the actual value.

Imperfect Competition Model

The imperfect competition model for simulation in the case where there are no price supports, no import quotas, and no marketing orders is:

$$(16)\ Q = f(BP)$$
$$(17)\ Q_f = g(P_f)$$
$$(18)\ Q_{Mi} = h(P_m)$$
$$(19)\ P_f + \theta_f \cdot Q_f/(\partial Q_f/\partial P_f) = P_m$$
$$(20)\ Q \equiv Q_f + Q_m + FUSE$$
$$(21)\ BP = (P_f \cdot Q_f + P_m \cdot Q_m)/(Q - FUSE)$$
$$(22)\ Q_I \equiv Q_{Mi} - Q_m$$

Exogenous Fluid Differential Model

The difference between the current imperfect competition model and the conventional exogenous fluid differential model is found in equation (19). The imperfect competition model is transformed to the exogenous fluid differential model used in most previous analyses by replacing equation (19) with:

$$(23) \qquad P_f = P_m + DIFF$$

where DIFF is the exogenous fluid price differential. It should be noted that DIFF is not the minimum Class I differential, but the effective fluid differential treated as an exogenous variable.

Comparison of Simulation Results

We used historical time periods for our simulations to avoid having to estimate the future values for exogenous variables. The dynamic simulation results, from 1980 to 1990, are shown in table 6.

Comparison of the two models illustrates how the imperfect competition model yields different estimates of deregulation effects from the results of

Table 6. Estimated Effects of Deregulation (Average of 1980–90)

	Fluid Milk Price	All Milk Price	Milk Production
		Percent Change	
Imperfect Competition Model	−15.2	−17.2	−4.2
Exogenous Differential Model	−16.1	−17.6	−4.3

the conventional exogenous fluid differential model.

The differences in results between the imperfect competition and exogenous fluid differential models tend to be rather small. For instance, results of the imperfect competition model show that, compared to the current level,[13] the fluid milk price would be 15.2% lower on an average for the simulation period, the blend price would be 17.2% lower, and milk production would be 4.2% smaller. Results of the exogenous fluid differential model show that the fluid milk price would be 16.1% lower on an average for the simulation period, the blend price would be 17.6% lower, and milk production would be 4.3% smaller.

In the imperfect competition model, $\partial P_f/\partial P_m$ is expressed by

$$\partial P_f/\partial P_m = 1/(1 + \theta_f) = 0.946 \tag{24}$$

where 0.946 is an average of simulation periods. This means that fluid milk prices decline by 95% of the magnitude of manufacturing price declines. In the exogenous fluid differential model,

$$\partial P_f/\partial P_m = 1 \tag{25}$$

Therefore, the exogenous fluid differential model tends to overestimate the negative effects of deregulation compared to the imperfect competition model, but the differences are relatively small. As equation (24) shows, the larger θ_f is, the smaller $\partial P_f/\partial P_m$. In other words, more fluid market imperfection could cause less direct translation of decreases in the manufacturing price into decreases in the fluid price.

Summary and Conclusions

The effective fluid price differential (the minimum differential plus any over-order payment) is considered to reflect the degree of competition in the U.S. milk market. An imperfect competition model with the fluid price differential endogenously explained by the degree of competitiveness is theoretically preferred to the exogenous fluid differential model because the fluid price differential is not exogenous due to over-order payments.

This paper presented the first imperfect competition model with an endogenous fluid differential for the U.S. dairy market using degree-of-competition parameter estimates. The estimated parameters imply that there is some degree of imperfection in the U.S. milk market, which has been declining over time. Competitive pressures in the fluid market have increased over time due to improvements in transportation technology and increasing reserves of milk in areas other than the Minnesota and Wisconsin. Dairy farmers have tried to reduce the competitive pressures by merging cooperatives and milk marketing orders while size of manufacturing plants have become larger. The gradually decreasing degree-of-competition parameters could be the consequences of a balance of power due to these developments.

The usefulness of the model was demonstrated by showing the relative differences of dynamic simulation results of the imperfect competition model with the results of an exogenous fluid differential model.

Because it is uncertain whether or not the current degree of market competition would remain unchanged after deregulation, we cannot determine that the imperfect competition model provides more likely estimates of key milk market parameters after deregulation than the exogenous fluid differential model. At a minimum, the exogenous fluid differential model tends to overestimate the negative effects of deregulation compared to the imperfect competition model, if the current degree of competitiveness in the U.S. milk market is maintained after deregulation. Decreases in the manufacturing milk price exactly correspond to decreases in the fluid milk price in the exogenous fluid differential model. However, some market imperfection could cause less direct translation of decreases in the manufacturing price into decreases in the fluid price.

Our simulation results show that the effects of deregulation are indeed larger with the exogenous fluid price differential model than with the imperfect competition model, but the differences are relatively small. This provides some justification for using the exogenous fluid price differential model as a simplifying, but acceptable alternative. There is a trade-off between realism and tractability in model building. If the losses associated with simplifying assumptions are small, it is often beneficial to make them and then concentrate on the parameters that impact the analysis most significantly. Since the degree of competition parameter has been declining in the U.S. dairy industry, researchers may not be guilty of a capital offense by treating the fluid differential as exogenous in some cases.

The model presented in this paper is a basic framework, and improvements in its shortcomings would be valuable in future research. In particular, processors' and manufacturers' market power is

[13] The current values are not observations but values solved by fully dynamic simulation of equations (7) to (12).

not explicitly incorporated into the current model, and over-order payments for Class II and III milk are aggregated in the effective fluid differential. Also, cooperatives with manufacturing plants are not considered, which is a characteristic of the U.S. dairy market that does in fact exist to an important degree.

Appendix

An Alternative Solution

For simplicity, fluid and manufacturing demand equations are specified as follows:

(A1) $$Q_f = a + bP_f$$

(A2) $$Q_m = c + dP_m$$

Then, equality across markets of "perceived" marginal revenue is:

(A3) $$P_f + \theta_f \cdot Q_f/b = P_m + \theta_m \cdot Q_m/d$$

In this paper, we attempted to estimate θ's from (A3) using estimates of (A1) and (A2).

Alternatively, substituting (A2) into (A3) yields;

(A4) $$P_f = -\theta_f/b \cdot Q_f + (1 + \theta_m)P_m + \theta_m \cdot c/d$$

If (A1) and (A4) are estimated without estimating (A2), both θ_f and θ_m are identified, but c and d cannot be identified separately.

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