Milk Marketing Orders and Sanitation Regulation:

Re-evaluating Marketing Orders' Welfare Effects

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This research shows that the existing literature on milk marketing orders misses an important effect. Previous work ignores the interaction of marketing orders with milk grading regulation. We model this interaction and show that producer benefits from marketing orders have been smaller than previous work suggests, and, under some conditions, may even be negative. Additional costs of producing fluid grade milk, omitted from previous welfare analyses, reduce producer benefits from marketing orders. Estimates of the additional cost indicate that this previously unmeasured effect is a significant component of the total welfare effect of marketing orders. An econometric model is developed to explain the variation in the fluid grade share of milk across states and time as a function of marketing order policy. Regression results support the hypothesis that marketing orders have encouraged the shift towards production of fluid-grade milk.

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1. Introduction and Background

This study provides a new perspective on the effectiveness of a key element of dairy policy in the United States. In particular, we show that the long literature on milk marketing orders missed an import aspect—the cost born by producers to participate in marketing orders. As a result, the existing welfare analysis of milk marketing orders is incomplete and misleading.

Since the turn of the 20th Century, U.S. milk production has been guided by sanitary regulations that distinguish between Grade A milk, eligible for fluid use and subject to highest sanitary standards, and Grade B milk, eligible only for manufacturing uses. The share of milk that meets Grade A standards has risen over time, but at different rates in different states. Meanwhile, the portion of Grade A milk used in fluid products has fallen over time, so more fluid grade milk is used in manufactured dairy products (Figure 1). Grade A milk in manufactured dairy products is of excess quality in the sense that Grade B milk is, by definition, suitable for use in these products and is cheaper to produce due to the lower sanitation standards. Why, then, have dairy farmers chosen to comply with stricter Grade A standards and incur the additional costs?

Federal and state governments play an important role in the pricing of milk, with marketing orders setting minimum prices for Grade A milk since the 1930s. Although marketing orders do not regulate sales of Grade B milk, they affect Grade B markets by changing the price of Grade A milk relative to Grade B. A large literature analyzing the economic effects of milk marketing orders focuses on their effects on price, quantity, and welfare in milk markets (Cox and Chavas, Dahlgran, Dobson and Salathe, Ippolito and Masson, Sumner and Wolf, among others). However, papers in this literature typically model Grade A milk markets exclusively, assume all milk is Grade A, or implicitly assume that milk grade is exogenous. In any case, these models take a narrow view of the incentives created by milk marketing orders. The main contribution of our research is to consider a broader set of incentives created by marketing orders by explicitly modeling the effect of marketing orders on both Grade A and Grade B markets. This innovation results in a revision of the standard welfare effects typically associated with milk marketing orders.

This paper is organized as follows. Section 2 sketches the new analytical model of milk marketing order regulation, and compares the effects of marketing orders on prices, quantities, and producer and consumer welfare to those found under the conventional model of milk marketing orders. Section 3 presents an estimate of the welfare cost of producing Grade A milk for the manufacturing market. Section 4 develops an econometric model of the Grade A share of milk, which is used to test the hypothesis that milk marketing orders have encouraged the observed shift towards Grade A milk. The data is described, and estimation results are presented. Section 5 concludes.

2. Modeling the Effect of Milk Marketing Orders on Milk Grade

Milk marketing orders raise the price paid to Grade A producers by discriminating against fluid milk consumers, pooling Grade A milk revenue from fluid and manufacturing markets, and paying a uniform, average price to all Grade A producers. Ippolito and Masson developed a model of regulated milk markets, building on Kessel's model of discriminatory pricing by the U.S. Federal Milk Marketing Order (FMMO) system (see also Parish, who precedes this literature with a model applied to Australian policy). This model, which has been adopted by many subsequent studies of milk marketing orders (e.g., Cox and Chavas, Dahlgran, Sumner and Wolf), has established what have come to be stylized facts of milk marketing orders effects. Price discrimination by marketing orders raises the relative price of fluid milk, reducing consumption of fluid milk and decreasing fluid-milk consumer surplus. Revenue pooling by marketing orders, together with discriminatory pricing, raises the average pay price of milk, inducing increased milk production and increasing producer surplus. By reducing fluid milk consumption and increasing milk production, revenue pooling also effectively subsidizes production of milk for manufacturing uses. Moreover, the regional implementation of marketing orders results in a regional distribution of costs and benefits associated with the policy (Cox and Chavas).

A New Model of Milk Marketing Order Regulation

Consider the following model of milk markets in a particular region:

(1) Fluid demand $Q_F = Q_F(P_F)$

(2) Manufacturing demand $Q_M = Q_M(P_M)$

(3) Total milk supply $Q_T = Q_T(P_M)$

(4) Market Clearing $Q_T = Q_M + Q_F$.

where Q_F and P_F denote quantities and prices on the fluid milk market, Q_M an P_M denote quantities and prices on the manufacturing milk market. Equation (1) is the local demand for fluid milk, equation (2) the portion of the national demand for manufacturing milk facing local producers, and equation (3) is the supply of all milk (Grade A and Grade B). The marginal producer price is assumed to be the manufacturing milk price, P_M, which is required for an interior equilibrium in which some Grade B milk is produced ($Q_B > 0$).

Equation (4) imposes the market-clearing condition that total quantity of milk supplied equals the total quantity demanded by the two markets.

Of the total quantity of milk, Q_T, only Q_F must be of fluid quality, or Grade A. For simplicity, we maintain the assumption of a constant additional marginal cost of producing Grade A milk, k, an assumption that may be relaxed. The model can accommodate either a competitive market equilibrium or a milk marketing order equilibrium by introducing the equilibrium relationship between fluid and manufacturing milk prices implied by either scenario. In what follows, we simulate the imposition of the marketing order on a competitive market, and analyze the effects on prices, quantities, and economic welfare.

The marketing order pricing scheme is as follows:

(5) $P_M = P_B$

(6) $P_F = P_M + D$

(7) $P_A = uP_F + (1\text{-}u)P_M$,

where $D > k$ is a fixed differential set by marketing orders, u is defined as the fluid utilization rate of Grade A milk, $u \equiv Q_F/Q_A$, and Q_A is the total quantity of Grade A milk. Substituting equations (5) and (6) into (7), the Grade A blend price can be written as

(8) $P_A = P_B + uD$.

Rearranging equation (8), the (interior) equilibrium quantity of Grade A milk under marketing order rules is:

(9) $(Q_F/Q_A)D = k$, or

(10) $Q_A = (D/k)Q_F$.

Thus, for $D > k$, the quantity of Grade A milk exceeds the quantity of fluid milk demanded, and some Grade A milk is sold on the manufacturing market. Under both regimes, the quantity of Grade B milk is equal to the difference between the total quantity of milk, Q_T, and the quantity of Grade A milk, Q_A.

In the absence of a marketing order, only milk sold on the fluid market gets the fluid-market premium, and the equilibrium relationship between fluid and manufacturing prices is

(11) $P_F = P_M + k.$

That is, at the margin, the premium paid for fluid-market milk just equals the additional cost of meeting Grade A standards. In this competitive case, only Grade A milk sold on the fluid market gets the fluid price, and thus only milk sold on the fluid market is Grade A: $Q_A = Q_F$.

Figure 2 illustrates the milk markets modeled by equation (1) through (10) for the case of a small geographic region whose producers face perfectly elastic demand for manufacturing milk. $Q_F(P_F)$ is the demand for fluid milk, P_M is the exogenous price for manufacturing milk, MC_B is the marginal cost of producing Grade B milk, and $MC_A = MC_B+k$ is the marginal cost of producing Grade A milk. Subscript "0" denotes competitive equilibrium prices and quantities, and subscript "1" denotes marketing order equilibrium prices and quantities. Under the competitive equilibrium, the total quantity of milk, Q_T, is determined by the intersection of the Grade B marginal cost curve, MC_B, and the exogenous price of manufacturing milk. Grade A producers supply quantity $Q_{A0} = Q_{F0}$ of fluid milk, resulting in fluid milk price $P_{F0} = P_M + k$, which satisfies the no-arbitrage condition expressed in equation (11). For $Q_A < Q_{A0}$, $P_F > P_M + k$ and producers can increase profits by producing more Grade A milk and selling it on the fluid market. For $Q_A > Q_{A0}$, $P_F < P_M + k$ so that producers can increase profits by producing less Grade A milk. In the competitive market, only fluid market milk meets Grade A standards. Grade B producers supply all manufacturing milk, $Q_{B0} = Q_T - Q_{F0}$.

The marketing order sets the fluid milk price as a fixed differential above the price for manufacturing milk: $P_{F1} = P_M + D$. For P_M exogenous, the marketing order determines the quantity of fluid demand, Q_{F1}. The curve labeled "P_{blend}" represents the Grade A blend price, equation (8), paid on all Grade A milk. The equilibrium Grade A quantity, Q_{A1}, satisfies the no-arbitrage condition expressed in equation (9), so that $P_{A1} = P_M + k$. That is, the Grade A quantity is found where the vertical distance between the blend price curve and P_M is equal to the vertical distance between the two marginal cost curves. By setting $D > k$, the marketing order raises the price of fluid milk and reduces the quantity of fluid milk demanded relative to the competitive market: $Q_{F1} < Q_{F0}$. The marketing order also results in more Grade A milk: $Q_{A1} > Q_{A0}$. For P_M exogenous, the total quantity of milk, Q_T, is the same as in the competitive market, so the marketing order results in less Grade B milk: $Q_{B1} < Q_{B0}$.

Recapping the key results: compared to the competitive scenario, the marketing order results in less milk sold to the fluid market and more Grade A milk produced, of which some is sold on the manufacturing market.

Note now the welfare effects of marketing orders. In competitive milk markets, $Q_{F0} = Q_{A0}$, and no Grade A milk is sold on the manufacturing market. In contrast, the marketing order results in a quantity $Q_{A1} - Q_{F1}$ of Grade A milk being sold on the manufacturing market. The additional cost of producing Grade A milk for manufacturing is $k(Q_{A1} - Q_{F1})$, or the area between the two marginal cost curves, from Q_{F1} to Q_{A1}. This cost is incurred by producers in order to participate in the marketing order, and must be considered in any welfare accounting of marketing orders' effects. In the next section, we discuss and evaluate analytically the cost of excess milk quality in the context of the welfare consequences of marketing orders for producers.

Producer Benefits from Milk Marketing Orders

The main rationale for milk marketing orders is that they make producers better off. Here we show that, when milk grade is taken into account, marketing orders do not necessarily make producers better off.

In competitive milk markets, total revenue for all milk is the sum of revenue from fluid and manufacturing markets:

$$
\begin{aligned}
(12)\qquad TR_0 &= P_{F0}Q_{F0} + P_M(Q_T - Q_{F0}) \\
&= (P_M + k)Q_{F0} + P_M(Q_T - Q_{F0}) \\
&= P_M Q_T + kQ_{F0}.
\end{aligned}
$$

From the last line in equation (12), total revenue is equal to the revenue from manufacturing milk price paid on all milk, plus a revenue from the premium paid for milk on the fluid market, kQ_{F0}. Total cost in the competitive market is

$$
(13)\qquad TC_0 = \int_0^{Q_T} MC_B(Q)\,dQ + kQ_{F0},
$$

where the second term is the additional cost of meeting Grade A standards for fluid market milk. Producer surplus in the competitive market is

$$
\begin{aligned}
(14)\qquad PS_0 &\equiv TR_0 - TC_0 \\
&= P_M Q_T + kQ_{F0} - \int_0^{Q_T} MC_B(Q)\,dQ - kQ_{F0}
\end{aligned}
$$

$$= P_M Q_T - \int_0^{Q_T} MC_B(Q)dQ.$$

Thus, in the competitive market, the additional revenue generated by the premium for fluid market milk, kQ_{F0}, just compensates producers for the additional cost of meeting Grade A standards on that milk.

Total revenue under the milk marketing order is also fluid milk revenue plus manufacturing milk revenue:

$$(15) \quad TR_1 = P_{F1}Q_{F1} + P_M(Q_T - Q_{F1})$$

$$= (P_{F1} - P_M)Q_{F1} + P_M Q_T$$

$$= DQ_{F1} + P_M Q_T$$

$$= [P_M Q_{A1} + DQ_{F1}] + P_M(Q_T - Q_{A1}).$$

Note that DQ_{F1} is revenue created by price discrimination against the fluid market and transferred to Grade A producers. Multiplying and dividing the term in square brackets by Q_{A1}, and applying the equilibrium condition from equation (9) ($d(Q_F/Q_A) = k$), total revenue can be written equivalently as

$$(16) \quad TR_1 = (P_M + k)Q_{A1} + P_M(Q_T - Q_{A1})$$

$$= P_M Q_{T1} + kQ_{A1}.$$

where $kQ_{A1} = DQ_{F1}$. In words, the marketing order creates rents DQ_{F1} on the fluid market and distributes them uniformly across all Grade A milk. In equilibrium, all Grade A milk, whether sold to the fluid or manufacturing market, gets a premium of k above the price of manufacturing milk. This is in contrast to the competitive scenario, where only milk sold on the fluid market gets the premium.

Total cost under the marketing order is

$$(17) \quad TC_1 = \int_0^{Q_T} MC_B(Q)dQ + kQ_{A1},$$

and producer surplus under the marketing order is

$$(18)\qquad PS_1 \equiv TR_1 - TC_1$$

$$= P_M Q_T + kQ_{A1} - \int_0^{Q_T} MC_B(Q)dQ - kQ_{A1}$$

$$= P_M Q_T - \int_0^{Q_T} MC_B(Q)dQ\,.$$

In the competitive case, the additional revenue from fluid market milk just compensates producers for the additional costs of producing fluid market milk. Under the marketing order, the additional revenue generated from Grade A milk – that is, fluid-eligible milk that may or may not be used in manufacturing – just compensates producers for the additional cost of meeting Grade A standards on that milk.

The change in producer surplus from introducing marketing orders into the competitive market is:

$$(19)\qquad \Delta PS \equiv PS_1 - PS_0$$

$$= P_M Q_T - \int_0^{Q_T} MC_B(Q)dQ - P_M Q_T + \int_0^{Q_T} MC_B(Q)dQ$$

$$= 0.$$

That is, according to this model, producers are no better off under the milk marketing order than they are in a competitive market! With constant k, the additional cost of producing Grade A milk exactly offsets the income transfer from fluid market consumers to producers. Previous welfare analyses applied to marketing orders have invariably excluded the additional cost of producing Grade A milk for manufacturing, thereby inflating the net benefit to producers.

The analysis can be generalized to allow for increasing marginal costs of meeting Grade A standards (k is increasing in Q_A). When k is increasing in Q_A, the income transfer from fluid market consumers exceeds the additional cost of meeting Grade A standards for the manufacturing market. This scenario and others are worked out in Balagtas. In all cases, the key point remains: the additional cost of meeting Grade A standards for the manufacturing market reduces producers' benefits from milk marketing orders.

3. Estimating the Cost of Producing Grade A Milk for Manufacturing

The work by Frank et al. provides the most recent estimate of the additional cost of Grade A milk production. Their conservative estimate of the cost of meeting the stricter Grade A sanitation standards is \$0.23 per cwt in 1974, or \$0.29 per cwt. in 1999 dollars. Due to heterogeneity among dairy farms, the additional costs surely vary from farm to farm. However, for any distribution of farms over costs, we may interpret the point estimate of \$0.29 as a measure of the center of the distribution, underestimating the additional costs of some individual farms, while overestimating that of others. Thus, for any region and year whose milk producers can be fairly represented by the sample used in the Frank, et al. study, \$0.29 times the quantity of Grade A milk used in manufacturing is an estimate of the total welfare cost due to excess quality.

However, the additional cost of compliance with Grade A standards is likely to have decreased over time due to changes in the industry. The average herd size of U.S. dairy farms has grown over time, so to the extent that the additional costs of meeting Grade A standards are fixed costs independent of herd size, the additional costs per cwt. of output will have fallen accordingly. The additional cost of Grade A milk also may have fallen over time due to changes in human capital. As farm management has improved through learning and through entry of new managers, the cost of meeting Grade

A standards likely has fallen. Further, as Grade B standards have risen closer to Grade A standards, the additional of cost of meeting Grade A standards has fallen.

In addition to variation in the time dimension, cost structures for dairy farms also vary regionally (Short, Kaiser and Morehart), so an estimate of production costs based on a sample of Wisconsin producers generally is not representative of the costs of producing milk in, for example, California or New York. Average herd size is a principal determinant of milk production costs that varies among regions (Kaiser and Morehart). To the extent that more stringent Grade A standards impose additional fixed costs independent of herd size, herd size is negatively correlated with the average additional cost of producing Grade A milk. Thus, the average additional cost of meeting Grade A standards is relatively low in those regions characterized by relatively large herd size.

To our knowledge, the data set that would capture regional and temporal variation in Grade B costs does not exist. Due to this lack of data, we use a simple method to approximate the variation in the additional cost of meeting stricter sanitary standards. We posit a simple functional form based on herd size:

(20) Additional cost per cwt. = 10.5 x $(\text{herd size})^{-1}$.

Equation (20) is decreasing in herd size, allowing for both cross-sectional and temporal variation in the additional cost of meeting Grade A standards. Further, it is calibrated to pass through the observation from Wisconsin, 1974 due to Frank et al. Consistent with the stylized facts, states characterized by larger herd sizes have lower costs, and as dairy farms across the country have tended towards larger herds, the additional cost of meeting Grade A standards has shrunk.

Using equation (20) and average U.S. herd size data from the U.S. Agricultural Census, we calculate the average additional cost of meeting Grade A Standards. The additional average cost between 1948 and 2000 ranged from a high $0.65 per cwt. in 1948 to a low of $0.10 per cwt. in 2000, with an average over that period of $0.28 per cwt.

Next, we define excess milk quality as Grade A milk sold on the manufacturing market, and the cost of excess milk quality as the additional cost of meeting Grade A standards for manufacturing milk. Here we calculate this cost based on the accounting cost estimate developed above.

The total cost of excess milk quality is the quantity of Grade A milk in manufacturing times the average additional cost of meeting Grade A standards. Using equation (20)–an accounting cost estimate adjusted by herd size–the social cost estimates hover near $100 million per year. Although the average additional cost of meeting Grade A standards fell over time, the total cost of excess milk quality does not fall because the quantity of Grade A milk is used in manufacturing is grew over time.

Many economists have quantified different aspects of the social costs of milk marketing orders (for example, Ippolito and Masson, Dahlgran, Cox and Chavas). None of these authors have included in their estimates the welfare cost of excess quality, which is in addition to the welfare triangles—fluid consumer losses, Grade A producer gains, manufacturing producer losses, and manufacturing consumer gains—typically associated with milk marketing orders. Table 1 summarizes the pertinent welfare effects found by these studies. The body of literature that conducts welfare analysis for milk marketing orders, but ignores the cost of excess quality, which this paper shows to be approximately $100 million per year, greatly underestimates the social cost of these programs.

Not only is the deadweight cost of milk marketing orders greater than previous thought, but the regulation has not been as beneficial to producers as previously believed since the additional cost of meeting Grade A standards is borne exclusively by Grade A producers. Ippolito and Masson estimate that Grade A producers' benefit from milk marketing orders is $211 million per year, or $268 million in 1999 dollars – a figure that is explicitly "gross of any regulation-induced expenditures" (p.54). Dahlgran finds that milk marketing orders raise Grade A producer surplus by $193 million per year, or $241 million in 1999 dollars. Cox and Chavas find that milk marketing orders raise producer surplus by $293 million per year, or $268 million in 1999 dollars (Cox and Chavas make no distinction between Grade A and Grade B milk). Subtracting $100 million from any of these measures of producer welfare significantly reduces the benefit that producers obtain from marketing orders.

Adjusting the annual costs of excess milk quality for forgone capital gains, and adding up the adjusted annual costs over the years, we can get a measure of how much waste has been generated by the excess milk quality induced by marketing orders. Using equation (20) and data on herd size and milk utilization from 1948 to 2000, and adjusting annual costs by a five percent annual interest rate, we calculate the capitalized cost of excess milk quality from 1948 to 2000 to be $23 billion.

4. Econometric Evidence of the Effect of Marketing Orders on Milk Grade

In this section we develop an econometric framework in which to test the hypothesis that the Grade A premium created by milk marketing orders resulted in a larger share of Grade A milk. This hypothesis has two dimensions: first, that the regional implementation of milk marketing orders was a determining factor of the regional pattern in the Grade A share of milk; second, that milk marketing orders encouraged a shift over time towards a larger Grade A share of milk in all states.

An Error Correction Model of the Grade A Share of Milk

I posit the following error correction model of the Grade A share of milk:

$$\text{(21)} \qquad \Delta Z_{it} = \alpha_i + \delta t + (\beta - 1)[Z_{it\text{-}1} - \gamma_P P_{it\text{-}1} - \gamma_H H_{it\text{-}1} - \gamma_A A_{it\text{-}1}] + u_{it}$$

where Δ is the first-difference operator, $Z \equiv \ln[S/(1\text{-}S)]$ is the log odds ratio of the Grade A share of milk (S), i indexes states and t indexes time in years, P is the Grade A premium, H is average herd size, and A (as in age) is the percentage of farm operators older than 65 years; α_i, δ, β and the γs are parameters to be estimated, and u is a random error. we use the log odds ratio of the Grade A share, a monotonic transformation of the Grade A share that is common for variables constrained to the [0,1] interval (Cox 1970). State-specific intercepts, α_i, are included to capture the effects of unobserved variables that influence differences in the Grade A share across states. Equation (21) represents fluctuations in the Grade A share for each state about its long-run trend, as well as variation in the Grade A share across states (see Davidson and MacKinnon p.683 and p.723, and Greene p.855-56 for standard expositions of the error correction model).

The Grade A premium, herd size, and the proportion of older operators are included as economic variables that affect the return to the Grade A investment. The primary variable of interest for this research is the Grade A premium created by marketing orders. The Grade A premium is the incentive for producers to produce Grade A rather than Grade B milk. We include average herd size and the portion of older operators as proxies for the additional cost of meeting Grade A standards. We use current observations on these variables as proxies for past and expected future streams of the profitability of Grade A milk production relative to Grade B milk production.

The time trend in equation (21) is included to capture the effect of the gradual convergence of Grade A and Grade B standards over time. Both sets of standards became stricter over time, and Grade B standards moved closer to Grade A standards over time. Converging standards reduced the additional cost of meeting Grade A standards.

The time trend also may pick up a reduced influence of the included economic variables on the Grade A share as shares moved closer to one. As the Grade A share approached the limit, the potential pool of producers who might switch to Grade A shrunk. As this occurred, the effect of the Grade A premium or the cost of meeting Grade A standards on the Grade A share also may have been reduced because fewer potential switchers were available to respond to increased profitability of switching to Grade A. Also, those producers who continued to produce Grade B milk perhaps faced the highest cost of switching, and thus were the least responsive to changes in the Grade A premium.

The short-run effect of the Grade A premium on the log odds ratio of the Grade A share in equation (21) is $(1 - \beta)\gamma_P$. To see this, add $Z_{it\text{-}1}$ to each side of the equation to get

(22) $$Z_{it} = \alpha_i + \delta t + \beta Z_{it\text{-}1} + (1 - \beta)[\gamma_P P_{it\text{-}1} + \gamma_H H_{it\text{-}1} + \gamma_A A_{it\text{-}1}] + u_{it}.$$

Then the short run effect of the Grade A premium is obtained from the partial derivative of equation (22) with respect to $P_{it\text{-}1}$:

(23) $$\left.\frac{\partial Z_{it}}{\partial P_{it-1}}\right|_{\text{short run}} = (1-\beta)\gamma_P .$$

That is, a change in the Grade A premium in year t results in a change in the Grade A share of $(1 - \beta)\gamma_P \Delta P_t$. Similarly, the short run effect of average herd size is $(1 - \beta)\gamma_H$, and the short run effect of the portion of older operators is $(1 - \beta)\gamma_A$. Note that the coefficient on the autoregressive term in the evolution of the Grade A share, β, must be strictly less than one in absolute value for this model to be stable.

The short run effects of the Grade A premium, herd size, and the portion of older operators build over time because of the persistence in the Grade A share. Dropping the time subscripts and error term from equation (21) and rearranging terms, the long-run equilibrium relationship can be expressed as

(24) $Z_{it}^* = \alpha_i/(1 - \beta) + \delta \mathrm{t}/(1 - \beta) + \gamma_P P_i^* + \gamma_H H_i^* + \gamma_A A_i^*$

where the asterisk denotes long run equilibrium values. Thus, the long run effect of the Grade A premium on the Grade A share is γ_P. That is, a unit increase in the Grade A premium raises the long run equilibrium Grade A share by γ_P. Similarly, the long run effects of herd size and the portion of older operators are γ_H and γ_A. Because differences across states in the Grade A premium, herd size, and operator age tend to persist, we expect the long run relationship implied by equation (24) to capture the variation in the data across states. Controlling for initial Grade A share, herd size, and operator age, the state with a higher Grade A premium will also have a higher equilibrium log odds ratio, and hence a higher Grade A share. The error correction model also captures the dynamics within states. If equation (24) defines the long-run equilibrium, the expression in square brackets of equation (21) is a measure of disequilibrium at time $t - 1$. Thus, equation (21) states that the (log odds ratio of the) Grade A share moves towards its equilibrium value at a rate that is proportional to the extent of disequilibrium.

Both short- and long-run effects of the Grade A premium are expected to be positive. Increases in the Grade A premium result in a larger share of Grade A milk. In the cross section, a state with higher Grade A premium, all else equal, will have a higher equilibrium Grade A share and will move more rapidly towards that equilibrium. Through their correlation with the cost of meeting Grade A standards, we expect the effect of average herd size to be positive, and the effect of the portion of older producers to be negative. Because most Grade A farms in year *t* will also be Grade A in year *t* + 1, the Grade A share evolves slowly over time, and we expect β is close to unity. Such persistence in the Grade A share is due to costly capital adjustment, which results in a relatively small short term response of the Grade A share to changes in the profitability of Grade A. Thus, the short run effects $(1-\beta)\gamma_P$, $(1-\beta)\gamma_H$, and $(1-\beta)\gamma_A$ are likely to be small in magnitude.

To facilitate linear regression, equation (21) can be restated as follows:

$$(25) \qquad \Delta Z_{it} = \alpha_i + \delta t + (\beta - 1)Z_{it\text{-}1} + \beta_P P_{it\text{-}1} + \beta_H H_{it\text{-}1} + \beta_A A_{it\text{-}1} + u_{it}$$

where $\beta_P \equiv (1-\beta)\gamma_P$, $\beta_H \equiv (1-\beta)\gamma_H$, and $\beta_A \equiv (1-\beta)\gamma_A$. Equation (25) is the estimating equation for the error correction model of the Grade A share. A test of the hypothesis that marketing orders have increased the Grade A share of milk can be stated as a test of the sign of β_P.

The error correction model is appropriate for both stationary and nonstationary data, and the interpretation of the model is the same regardless of the presence or absence of unit roots in the data. Under the assumption that the Grade A share and some of the explanatory variables are nonstationary, the only additional concern is in regards to the long run relationship between trending variables. For the error correction model to make sense, nonstationary variables in the model must share a common stochastic trend such that the long-run relationship among them is stable. If this condition is met, the variables are said to be cointegrated. Nonstationary variables that are not cointegrated will tend to diverge, and cannot be expected to behave according to any long-run relationship. Under the assumption of nonstationarity, statistical significance of the coefficient on the error correction term, $(\beta - 1)$, is evidence of cointegration.

Economic theory suggests that the Grade A premium, herd size, and operator age are simultaneously determined with the Grade A share. Following equation (3.4), the Grade A premium is a function of the quantity of Grade A milk, the quantity of fluid-use milk, and the fluid price differential set by marketing orders. Herd size and operator age are results of investment decisions that are affected by the price of milk, including the Grade A premium. Thus, herd size and operator age are also simultaneously determined with the Grade A share. Durbin-Wu-Hausman tests for exogeneity indicate that the Grade A premium is endogenous, while the herd size and operator age is exogenous. we take a two-stage least squares (2SLS) approach to treat endogeneity of the Grade A premium.

As always, the challenge of a 2SLS approach is finding appropriate instruments for the endogenous regressors. We find three instruments in the marketing order pricing scheme. The Grade A premium is defined by equation (8). Rearranging equation (8), the Grade A premium can be stated as:

$$(26) \qquad P_{it} \equiv P_{Ait} - P_{Bit} = \frac{Q_{Fit}}{Q_{Ait}} D_{it}$$

The equilibrium quantity of fluid milk, Q_F, is also endogenous since both the quantity of fluid milk demanded and the Grade A premium are functions of the price of fluid milk. However, state population and per capita income are proxies for Q_F that we take as exogenous. (See Johnson, Stonehouse, and Hassan for a review of the literature of the determinants of fluid milk demand)

Equation (26) also indicates that the fluid milk premium, D, is a determinant of the Grade A premium. Recall that the fluid milk premium is added to the manufacturing milk price to set the fluid milk price, and is determined administratively. As such, we take the fluid milk premium to be exogenous to the system.

The first-stage regression then is:

$$P_{it} = a_i + a_{pop}Population_{it} + a_{inc}Income_{it} + a_D D_{it} + a_{trend}t + e_{premiumit} \quad (27)$$

Econometric Results

The model is estimated using data spanning 30 states and 43 years from 1950 to 1992. The data are described in detail in Balagtas. We estimate three variations of the error correction model of the Grade A share of milk:

- Model 1: OLS on equation (25);
- Model 2: GLS on equation (25), assuming state-wise heteroscedasticity (i.e., state-specific error variance);
- Model 3: Two-stage GLS on equation (25), treating Grade A premium as endogenous, assuming state-wise heteroscedasticity;

The data are described in detail in Balagtas. Results are reported in Table 2. Across all specifications and estimators, the estimated effect of the Grade A premium on the Grade A share is positive, as expected. The coefficient on the Grade A premium is estimated with precision in each model, with statistical significance at the one-percent level. Although the OLS estimate is larger, estimates are all of similar magnitude across estimators, suggesting robustness to the various specifications.

The estimated coefficient on the lagged log odds ratio is negative across all specifications, indicating that the log odds ratio is stable ($\beta < 1$). The proximity of the estimate to zero, and hence the proximity of β to 1, indicates strong persistence in the Grade A share, as expected.

The effect of operator age is measured imprecisely. The estimated coefficients on operator age are greater than zero in all three specifications. An interpretation of these results is that the experience and skills of older operators yield cost-savings that compensates for their shorter time-horizon and older capital vintage, increasing the profitability of Grade A milk production. The effect of average herd size is also measured imprecisely. Moreover, the GLS estimates of the coefficient on herd size are not of the expected sign.

The key result is the estimated effect of the Grade A premium on the Grade A share. The positive coefficients on the Grade A premium support the hypothesis milk marketing orders helped determine the geographic pattern of the Grade A share, with high Grade A premiums inducing high Grade A shares. The positive effect of the Grade A premium also supports the hypothesis that milk marketing orders encouraged the shift towards Grade A milk production over time.

Following equation (23), results from Model 3 indicate that the short-run effect of the Grade A premium on the Grade A milk share is 0.0336. That is, controlling for initial Grade A share, herd size, and operator age, an additional \$1.00 on the Grade A premium increased the log odds ratio by 0.0336 in the first year. (To put a \$1.00 increase in the

Grade A share into perspective, the sample mean Grade A premium is \$1.959, and the standard deviation in the Grade A premium is \$1.507 (Table 1)). Converting to Grade A shares, for a state with an initial Grade A share of 50 percent, a \$1.00 increase in the premium, ceteris paribus, increased the Grade A share by approximately 0.8 percentage points, or 1.6 percent, to 50.8 percent (= $e^{0.0336}/(1+e^{0.0336})$) in the first year. Over time, the effect is larger. The long run effect of the Grade A premium on the log odds ratio of the Grade A share is $\gamma_P = \beta_P/(1-\beta) = 0.0336/0.0430 = 0.7814$. For a state with an initital Grade A share of 50 percent, a \$1.00 increase in the Grade A premium, ceteris paribus, increased the Grade A share by 18.6 percentage points to 68.6 percent (= $e^{.7814}/(1+e0^{.7814})$).

5. Conclusion

This research shows that the existing literature on milk marketing orders misses an important effect. Previous work ignores the interaction of marketing orders with milk grading regulation. We model this interaction and show that producer benefits from marketing orders have been smaller than previous work suggests, and, under some conditions, may even be negative. Additional costs of producing fluid grade milk, omitted from previous welfare analyses, reduce producer benefits from marketing orders. Estimates of the additional cost indicate that this previously unmeasured effect is a significant component of the total welfare effect of marketing orders. A dynamic stochastic econometric model is developed to explain the variation in the fluid grade share of milk across states and time as a function of marketing order policy. Regression results support the hypothesis that marketing orders have encouraged the shift towards production of fluid-grade milk.

The key result is that marketing orders encourage the production of Grade A milk instead of Grade B milk for the manufacturing milk market. Moreover, Grade A producers incur additional production costs of meeting Grade A standards. This cost reduces producers' benefits from marketing orders. The entire previous literature on milk marketing orders ignores this cost, and thus overstates producers' benefits from marketing orders.

Figure 1. Grade A Share of All Milk, and Share of Grade A Milk Used in Fluid Products, U.S. 1948-2000

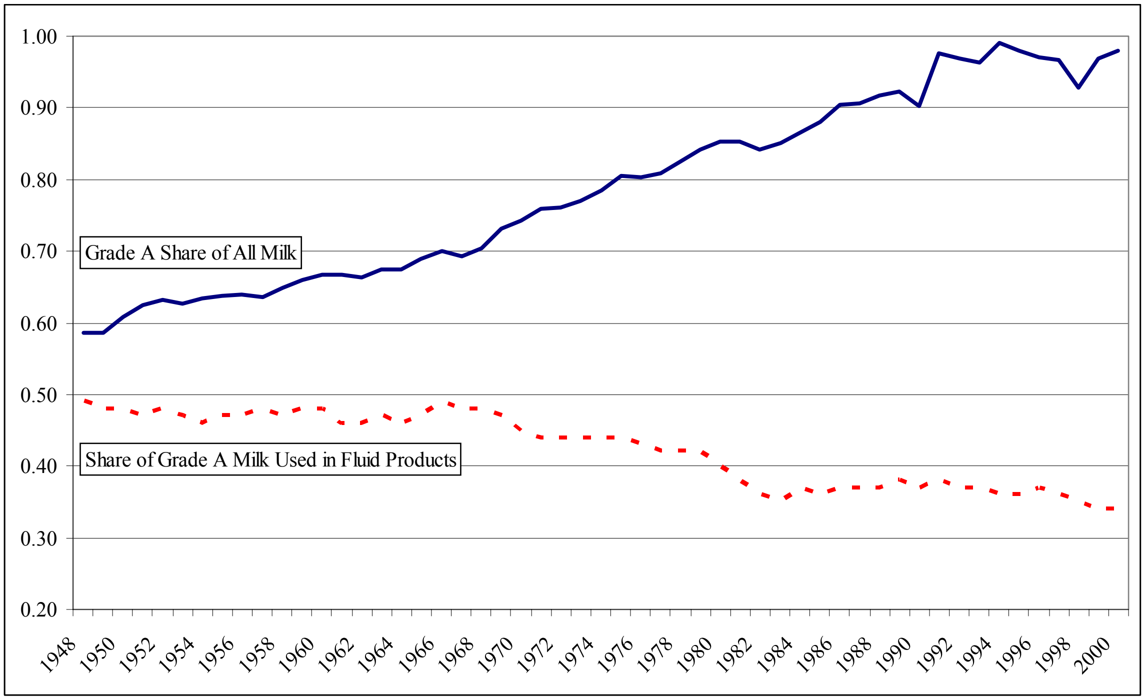

Figure 2. Milk Marketing Orders, with Exogneous Manufacturing Milk Price

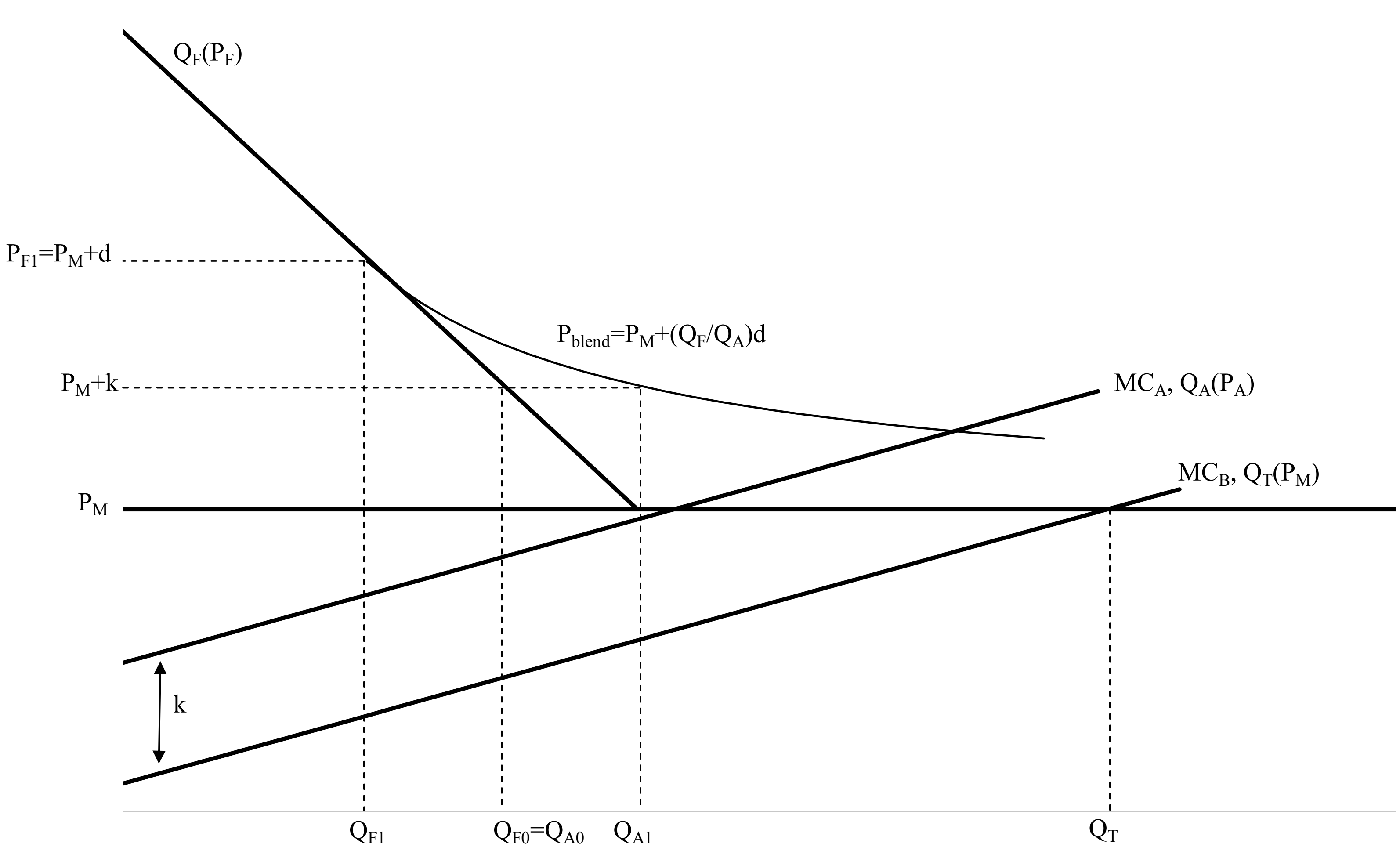

Table 1. Estimated Welfare Effects of Milk Marketing Orders from the Agricultural Economics Literature

Authors	Gain to Grade A Producers	Deadweight Cost
	1999 $ million[1]	
Ippolito and Masson	268	76
Dahlgran	241	121
Cox and Chavas	268	135[2]

1/ Adjusted by the PPI for All Farm Products. 2/ Does not include administration costs.

Table 2. Regression results for the error correction model of the Grade A share of milk—dependent variable: change in the log odds ratio of the Grade A share

	Model 1	Model 2	Model 3
Estimator	OLS	GLS	2SLS
Heteroscedasticity[2]	no	yes	yes
Lagged log odds ratio	-0.0533*	-0.0424*	-0.0430*
	(0.0076)	(0.0070)	(0.0076)
Lagged Grade A premium	0.0261*	0.0259*	0.0336*
	(0.0071)	(0.0056)	(0.0091)
Lagged % operators > 65 years	0.3433	0.1973	0.3408
	(0.2801)	(0.2047)	(0.2217)
Lagged herd size	0.0020	-0.0141	-0.0065
	(0.0213)	(0.0275)	(0.0277)
Trend	0.0055*	0.0051*	0.0052*
	(0.0010)	(0.0008)	(0.0009)
Constant	----- state-specific intercepts suppressed -----		
Total observations	1282	1282	1282
States	30	30	30
Years per state[3]	42.7	42.7	42.7
Significance of the regression[4]	133.35*	150.13*	351.90*

Note: standard errors are in parentheses. An asterisk (*) denotes statistical significance at the 1 percent level.
1/ Grade A premium treated as endogenous.
2/ State-specific error variance.
3/ Average observations per state.
4/ Wald χ^2 statistic for the test of the significance of the regression.

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