Effects of Milk Marketing Order Regulation on the Share of Fluid-Grade Milk in the United States

Joseph V. Balagtas, Aaron Smith, and Daniel A. Sumner

The share of raw milk meeting fluid quality (Grade A) standards in the United States rose steadily through the latter half of the twentieth century, but a shrinking portion of that was used in fluid products. Grade A milk exceeds the quality standards for the manufactured products for which it has been increasingly used. We present an econometric model that exploits regional and temporal variation in policy implementation to identify the effect of marketing orders on the Grade A share of milk. Results support the hypothesis that marketing orders significantly encouraged the growth in the Grade A share of milk.

Key words: error correction model, excess quality, price regulation, rent dissipation.

Milk marketing orders are central to dairy market regulation in the United States. Since the Agricultural Marketing Agreement Act (AMAA) of 1937 and similar state legislation of the same period, federal and state governments have administered marketing orders that determine minimum prices that processors must pay farmers for fluid-grade milk. These marketing orders have significantly influenced the economic performance of milk markets. In this paper, we show empirically that marketing orders have helped increase the production of fluid-grade milk beyond the demand for fluid milk.

Because the industry is large and the policies have important economic consequences, milk marketing orders are among the most studied of all agricultural policies (see, among others, Cox and Chavas 2001; Dobson and Salathe 1979; Ippolito and Masson 1978; Kessell 1967; Sumner and Wolf 1996). This literature has established what have come to be stylized facts of milk marketing orders. Price discrimination by marketing orders raises the relative price of milk used in beverages (fluid milk), reducing consumption of fluid milk and decreasing economic surplus of consumers of fluid milk. Revenue pooling by marketing orders, together with discriminatory pricing, raises the average producer 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, resulting in a lower price for such milk and for consumers of products like cheese, butter, and milk powder. Moreover, the degree of price discrimination varies by region, as do supply and demand parameters, resulting in welfare effects that also vary by region (Cox and Chavas 2001).

However, this important literature generally abstracts from a crucial feature in the implementation of milk marketing orders. Milk sanitation standards in the United States distinguish between milk eligible for use in fluid products, known as Grade A milk, and milk eligible only for manufactured dairy products, known as Grade B milk. The milk grade designation is made at the farm level, such that all milk from a given farm is either fluid or manufacturing grade. The highest standards are set for Grade A milk because of the food safety risks associated with fluid milk products. Marketing orders regulate only Grade A milk, and do not regulate Grade B milk. By raising the price of Grade A milk relative to Grade B milk, marketing orders raise the incentive to

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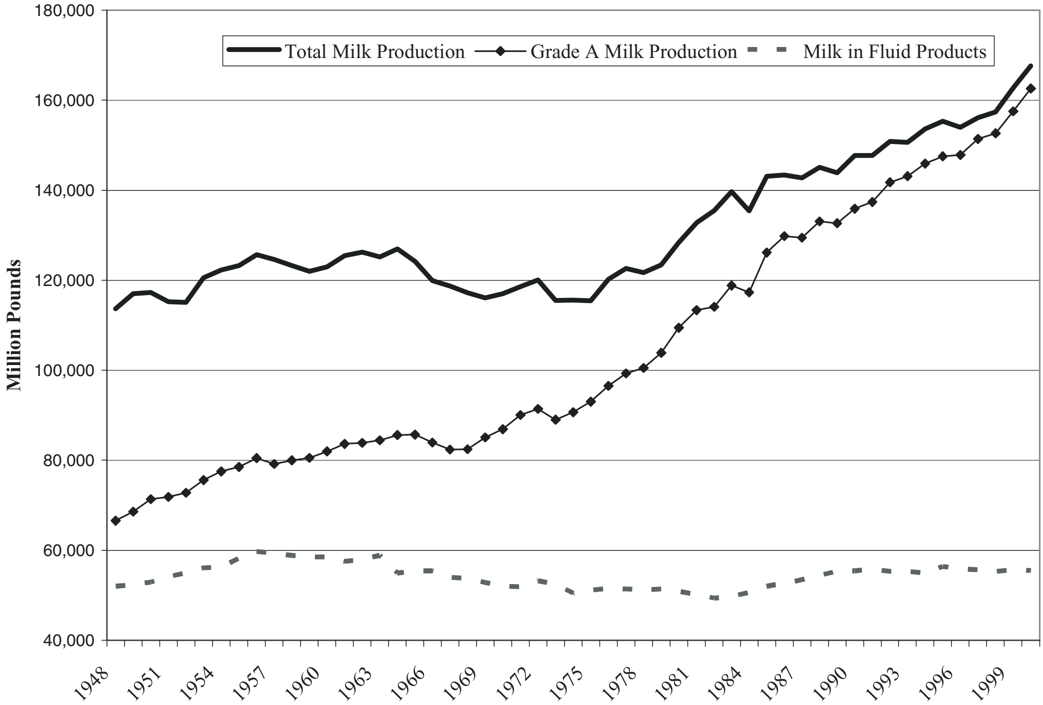

Source: For the total milk production and Grade A milk production: USDA-NASS (d). Source for milk used in fluid products: USDA-NASS (b).

Figure 1. Total milk production, Grade A milk production, and milk used in fluid products, United States 1948–2000

produce Grade A milk relative to Grade B milk.

The Grade A share of total milk production in the United States rose steadily through the latter half of the twentieth century. The Grade A share of milk grew from 59% in 1948 to 98% in 2000 (figure 1). The dramatic shift in the milk grade mix toward Grade A is remarkable in the context of the uses to which Grade A milk has been put. The quantity of milk used in fluid products has changed little since World War II. However, total milk production has grown dramatically, as has Grade A milk production, so that the share of Grade A milk actually used to make fluid products has fallen from 78% in 1948 to 34% in 2000 (figure 1). Thus, the share of milk satisfying the relatively high fluid standards grew, while a shrinking share of this milk was used in the fluid products.

Grade A milk not used in fluid products is used in manufactured dairy products where it is a substitute for Grade B milk. Given the difference in sanitation standards, Grade A milk is cleaner than necessary for use in manufactured dairy products; Grade A milk exceeds manufacturing grade standards. In this sense, Grade A milk used to make manufactured dairy products is of excess quality, which comes at the cost, borne by producers, of meeting the stricter standards for Grade A milk.

Economic intuition suggests a link between milk marketing order policy, which raises the relative price of Grade A milk, and the observed shift toward Grade A milk production in the United States. Indeed, a small number of extension reports by agricultural economists suggest that these observed patterns were driven at least in part by a conversion of farms from Grade B to Grade A in response to marketing order regulation (Bartlett 1964; Cummins 1978; Frank, Peterson, and Hughes 1977; Graf and Jacobson 1973). Yet the literature dedicated to the subject of modeling and measuring the effects of milk marketing orders on prices, quantities, and economic welfare has largely ignored the interaction between marketing order regulation and milk sanitation regulation. A recent exception is Balagtas and Sumner (2005), who show that the previous literature overstates producer benefits and understates the social costs of milk marketing orders.

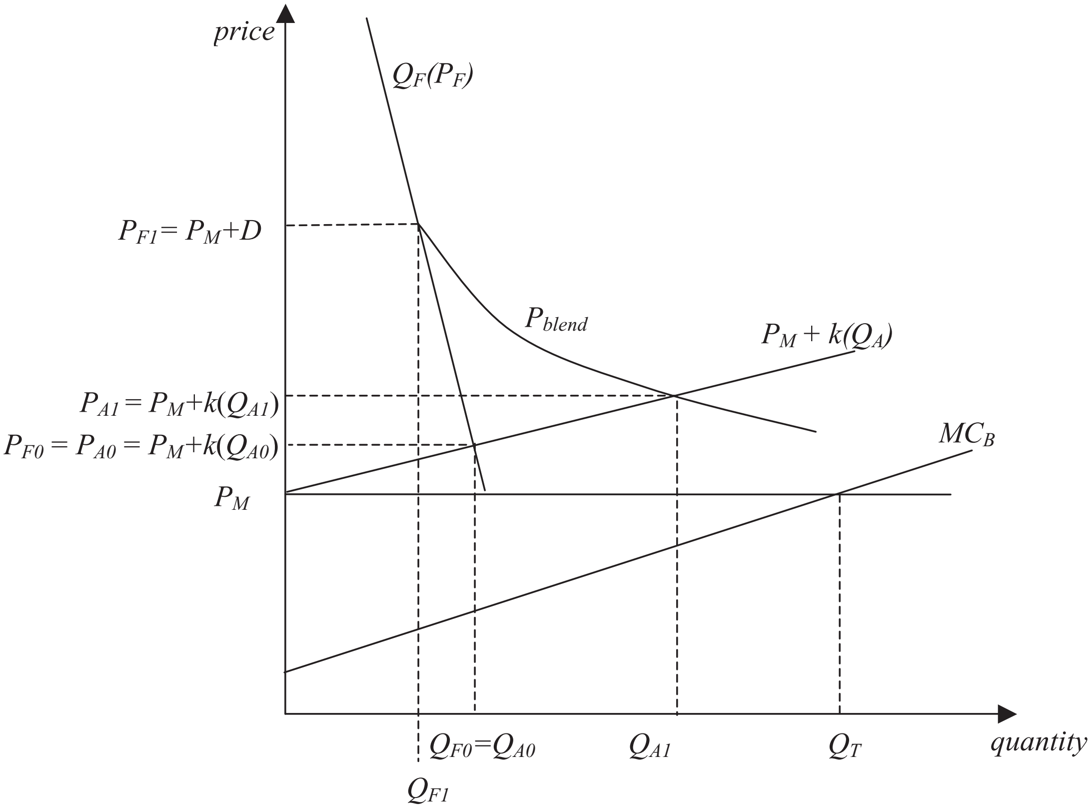

Figure 2. The effects of milk marketing orders on milk markets

This article develops an econometric model to test the link between milk marketing order policy and milk grade. We model the Grade A share of milk as a dynamic stochastic process influenced by the costs and benefits of Grade A conversion. To measure the benefits of conversion, we use the premium paid for Grade A milk relative to Grade B milk. In the next section, we show how this Grade A premium captures price discrimination and revenue pooling by marketing orders. To identify the effect of marketing orders on the Grade A premium and, in turn, on the Grade A share, we exploit exogenous variation in marketing order policy over time and across states. We find strong econometric support for the hypothesis that marketing orders raise the premium paid for Grade A milk, which in turn encourages a shift toward the production of Grade A milk for manufactured dairy products. We conclude that marketing orders have contributed to excess milk quality, and that the standard welfare analysis of milk marketing orders has omitted the cost of excess quality.

Conceptual Framework

Milk marketing orders raise the price of Grade A milk through price discrimination and revenue pooling (Kessell 1967; Ippolito and Masson 1978; Cox and Chavas 2001; Sumner and Wolf 1996; among others). Figure 2 illustrates the effects of a marketing order on a milk market. (See Balagtas and Sumner 2005 for the more detailed analytics of milk marketing orders.) In the figure, fluid milk demand is $Q_F(P_F)$, manufacturing milk demand is perfectly elastic at price P_M, and the marginal cost of producing Grade B milk is MC_B. Given that producers could sell milk on the manufacturing market at price P_M, the marginal cost of producing Grade A milk is $MC_A = P_M + k(Q_A)$, where the additional cost of meeting Grade A standards, $k(Q_A)$, is increasing in Q_A. In the absence of milk marketing orders, milk sold to the fluid market gets a premium that just compensates producers for the additional costs of meeting Grade A standards. The price of milk sold on the fluid market is $P_{F0} = P_M + k(Q_{A0})$, and just enough Grade A milk is produced to meet fluid milk demand at that price ($Q_{A0} = Q_{F0}$). Total milk production, Q_T, is found where P_M intersects MC_B, and all milk sold on the manufacturing market is Grade B milk, $Q_{B0} = Q_T - Q_{F0}$.

The marketing order sets the price of fluid milk as a fixed differential over P_M, $P_{F1} = P_M + D (D > k)$, thus reducing fluid milk consumption to Q_{F1}. The price discrimination scheme is implemented through revenue pooling, which pays a uniform "blend" price for all Grade A milk sold in fluid and manufacturing markets, where

$$(1) \qquad P_{\text{blend}} = P_M + (Q_F/Q_A)D.$$

Grade A milk production, Q_{A1}, is found where P_{blend} exceeds P_M by the additional cost of meeting Grade A standards: $P_{A1} = P_M + k(Q_{A1})$. Total milk production is still Q_T, and Grade B milk production is $Q_{B1} = Q_T - Q_{A1}$. Thus, the marketing order raises the price of Grade A milk, inducing some producers to shift from Grade B to Grade A. As a result, the quantity and share of milk meeting Grade A standards rise, although total production is unchanged and the quantity sold to the fluid market decreases. This stylized model of milk marketing orders is consistent with the data showing dramatic growth in the Grade A share of milk coupled with a reduction in the share of all milk used in fluid products (figure 1).

Previous authors have noted the welfare effects of milk marketing orders. Price discrimination and revenue pooling transfers wealth from fluid milk consumers to Grade A milk producers and manufacturing milk consumers (Ippolito and Masson 1978; Cox and Chavas 2001; Sumner and Wolf 1996). Balagtas and Sumner (2005) showed that rents created by milk marketing orders were dissipated by the costs of compliance with Grade A standards. In figure 2, wealth transferred to Grade A milk producers, $(P_{A1} - P_M)Q_{A1} - (P_{A0} - P_M)Q_{F0}$ is partially offset by the additional cost of meeting Grade A standards for milk sold to the manufacturing market, $\int_{Q_{F0}}^{Q_{A1}} k(q)\,dq$.[1] Balagtas and Sumner show that the cost of excess milk quality comprises a substantial portion of the total social cost of the milk marketing orders.

This paper develops econometric evidence of the impact of milk marketing orders in determining two variables related to milk grade. First, we consider the impact of milk marketing orders on the premium paid for Grade A milk. Then, we discuss how the Grade A premium influences the choice of milk grade by dairy farms and, therefore, the Grade A share of milk.

Marketing Orders and the Premium for Grade A Milk

A dairy farmer will switch from Grade B to Grade A if the discounted expected benefits from switching exceed the discounted expected costs.[2] Thus a key determinant of milk grade is the difference between the Grade A and Grade B milk prices, which we term the Grade A premium. Subtracting P_M from both sides of equation (1) yields the Grade A premium

$$(2) \qquad Premium = P_{\text{blend}} - P_M = (Q_F/Q_A)D$$

which is a product of the administratively determined fluid milk differential, D, and the proportion of Grade A milk that goes to the fluid market, Q_F/Q_A.

Regional implementation of marketing order policy is such that D differs across regional marketing orders. Furthermore, fluid milk differentials have changed over time, as have milk consumption and Grade A milk production. We exploit the geographic and temporal variation in the fluid milk differential to identify the effect of marketing orders on the Grade A premium, positing the following econometric model:

$$(3) \qquad \ln Premium_{it} = a_0 + a_{\text{pop}} \ln Population_{it} + a_{\text{inc}} \ln Income_{it} + a_D \ln D_{it} + a_{\text{trend}} t + e_{it}$$

where $Premium_{it}$ is the Grade A premium in state i in year t, *Population* and *Income* are demand shifters, and e is a random error. A trend is also included to capture changes in demand for fluid milk not associated with population and income. The parameter of main interest is a_D, the elasticity of the Grade A premium with respect to the fluid milk differential set by

[1] If $k(.)$ were constant in Q_A, the additional costs of meeting Grade A standards would completely dissipate marketing order rents.

[2] This discussion also applies to new entrants into dairy farming. In the case of the new entrant, the milk grade decision can be framed as a problem of choosing among alternative (Grade A or Grade B) technology sets.

marketing orders. From equation (2), D affects the Grade A premium both directly and indirectly through the fluid milk ratio, Q_F/Q_A. The elasticity parameter a_D would equal one if D had no effect on Q_F/Q_A. However, because the marketing order increases the supply of Grade A milk, an increase in D decreases Q_F/Q_A and therefore $a_D < 1$.

Other variables may also contribute to the Grade A premium. In recent years, milk processors have paid premia (in excess of minimum prices set by marketing orders) for specific milk quality characteristics. Premia paid for milk characteristics that are not associated with milk grade, such as milk fat content, are milk-grade neutral. However, in the mid 1980s, dairy scientists established a link between cheese yield and somatic cell count (SCC) in milk (e.g., Politis and Ng-Kwai-Hang 1988).[3] Since then, cheese plants have often offered premia for low somatic cell count. While physical infrastructure on the farm, not milk quality, was often the most important barrier to Grade A (Chite 1991), maximum SCC for Grade A is lower than that for Grade B. To the extent that SCC premia are positively correlated with Grade A-ness, such incentives encouraged producers to switch to Grade A. In our econometric model of the Grade A premium, such private premia for Grade A milk are left in the error term. However, we are aware of no evidence that the private premia are correlated with marketing order policy, thus have no reason to believe that the private premia in the error term induce omitted variable bias.

The Additional Cost of Producing Grade A Milk

Conceptually, dairy farms choosing milk grade weigh the Grade A premium against the additional cost of producing Grade A milk. Thus, before developing our model of the Grade A share of milk, we discuss some conceptual issues pertaining to the cost of conversion. Stricter sanitary standards for Grade A milk result in added costs for Grade A dairy farms relative to Grade B farms. Additional variable costs include more diligent cleaning and maintenance of equipment and facilities, and more frequent inspections. The importance of additional investment costs depend on the existing capital stock on the farm. In the past, conversion to Grade A might have required, for example, replacing milk cans with a bulk milk tank and stainless steel piping, or replacing or upgrading existing dairy buildings, or upgrading existing water supplies and plumbing (USDHHS; USDA-AMS (b); Chite 1991). Some of these technologies, such as refrigerated milk tanks, were adopted widely by dairy farms of both grades, and arguably would have been adopted by Grade A and Grade B farms in the absence of milk marketing orders as existing capital depreciated and was replaced.

Technological change is potentially an important factor in the milk-grade decision on dairy farms. Technological change has encompassed not only improved dairy herd genetics and advances in animal health and nutrition management, but also important changes to milking equipment and facilities (Gardner 2002, pp. 14–16). Typically, new milking equipment and facilities have been designed to meet Grade A milk quality standards. Thus, adoption of the newest production technologies reduces the costs of meeting Grade A standards, and the milk grade choice on farms was closely linked to technology adoption that had little or nothing to do with milk grade. As part of the capital replacement problem, the timing of a switch from Grade B to Grade A milk production is influenced not only by the price and marginal value product of new capital, but also by the depreciation rate, salvage value, and marginal value product of existing capital. Farms using older, more obsolete capital *ceteris paribus* may face higher costs of purchasing and installing new capital, but have a lower opportunity cost of capital replacement. New entrants perceive no opportunity cost of replacement, and thus are more likely to adopt the latest capital and, because new capital tends to be compliant with Grade A standards, produce Grade A milk.

The technological change on dairy farms has been accompanied by sweeping changes in dairy farm structure. The number of dairy farms, like the number of all farms, fell throughout the twentieth century, while average herd size grew. The number of dairy operations in the United States fell from 1.1 million in 1965 to 105,000 in 2000. The number of dairy cows fell to 9 million in 2000 from 14 million in 1965 and 21 million in 1924 (USDA-NASS (c)). To the extent that the investment required to meet Grade A standards is fixed for herd size, the Grade A investment requirements were not herd-size neutral; farms milking more cows are able to spread the fixed costs

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[3] Somatic cell count measures the number of white (i.e., somatic) cells in milk. High SCC is associated with mastitis.

associated with, say, installing new plumbing, across more milk, thus lowering the average cost of meeting Grade A standards.

Rapid technological change potentially reduces the market value of existing farm capital. Thus, the time horizon of the farm owner or manager also may influence the milk grade choice. Farmers closer to retirement age, and without familial heirs to the farm, have less time over which to recover any investment costs, and thus perceive a smaller expected net present value of a switch to Grade A. Industry interviews indicate that some of the last Grade B dairy farms in recent years were older farmers using up existing human and physical capital until retirement.

A Conceptual Model of the Grade A Share of Milk

The Grade A share of milk in a state is a function of the discounted present value of the net benefits of producing Grade A milk relative to Grade B milk for producers in the state. Also, the Grade A share in a state exhibits serial correlation because of irreversibility of the investment associated with Grade A, and the gradual replacement of capital, which contribute to a slow evolution of the Grade A share over time. A general conceptual model of the Grade A share is

$$(4)\quad S_{it} = f(S_{it-1}, BENEFITS_{it-1}, COSTS_{it-1})$$

where S is the Grade A share of all milk in state i, year t, $BENEFITS$ is the discounted present value of expected benefits from choosing Grade A, and $COSTS$ is the discounted present value of the additional costs of meeting Grade A standards. Here, the Grade A share in year t depends on the Grade A share in $t-1$, and also on the discounted stream of costs and benefits as expected in year $t-1$.

Heterogeneity among dairy farms results in Grade A shares greater than zero and less than one, even though producers in a state face similar expected prices. The stock and depreciation rate of dairy capital (human and physical) may differ across farms, as may herd size, time horizon, or discount rates. Variation across states in the Grade A share of milk is a function of producer heterogeneity across states, as well as differences in milk prices.

Development of an econometric model based on equation (4) requires data on S, $BENEFITS$, and $COSTS$, as well as specifying a functional form for f. Our proxy for expected benefits is the Grade A premium (*Premium*). As one proxy for expected costs, we use average dairy herd size (*Herd*).[4] As a second proxy for costs, we use the proportion of dairy farmers older than 65 years (*Age*) to capture the effects of the value of existing capital and the time horizon of dairy farms. We discuss our data in greater detail in the next section.

Substituting our data into equation (4) yields

$$(5)\quad S_{it} = f(S_{it-1}, Premium_{it-1}, Herd_{it-1}, Age_{it-1}).$$

The marginal effect of the Grade A premium is expected to be positive: $\partial S_{it}/\partial Premium_{it-1} > 0$. The larger is the Grade A premium, *ceteris paribus*, the greater is the return to Grade A milk production relative to Grade B milk production, and the larger is the Grade A milk share. The marginal effect of herd size is a priori ambiguous, and depends on the relative importance of compliance costs that vary with herd size as opposed to those that are fixed. That is, if costs are increasing in herd size, larger farms will find it costlier than smaller farms to convert to Grade A, *ceteris paribus*. Nor does theory provide an unambiguous prediction of the marginal effect of the proportion of older operators on the Grade A share. A positive relationship between operator age and (human and physical) capital vintage would suggest that older operators may have a larger investment cost to comply with Grade A standards. Also, a shorter time horizon for older operators may inhibit new investment. On the other hand, farms using older capital may have a lower opportunity cost of capital replacement. Furthermore, the experience and skills of older operators may reduce the costs of meeting Grade A standards. Thus, the net effect of the proportion of older operators on the Grade A share of milk is ambiguous.

The trend toward 100% Grade A is a key characteristic of the data that we seek to explain as a function of economic variables. The discussion and analysis above suggest that the Grade A milk share is a dynamic process driven by investment decisions on

[4] To the extent that prices differed for Grade A and Grade B milk, milk grade may influence a farm's optimal herd size, in which case herd size and the milk grade decision might be thought of as a joint decision. Durbin–Wu–Hausman tests for exogeneity suggest herd size is exogenous (Durbin 1954; Hausman 1978; Wu 1973).

farms, and thus by the expected returns to investment. We next develop a dynamic stochastic econometric model of the Grade A milk share and use it, together with our model of the Grade A premium, to test the hypothesis that marketing orders resulted in a larger share of Grade A milk.

Specification of the Econometric Model of the Grade A Share of Milk

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

$$(6) \qquad \Delta Z_{it} = \alpha_i + \delta t + (\beta - 1)[Z_{it-1} - \gamma_P Premium_{it-1} - \gamma_H Herd_{it-1} - \gamma_A Age_{it-1}] + u_{it}$$

where Δ is the first-difference operator, $Z = \ln[S/(1 - S)]$ is the log odds ratio of the Grade A share of milk; α_i, δ, β and the γs are parameters to be estimated, and u is a random error.[5] State-specific intercepts, α_i, are included to capture the effects of unobserved variables that influence differences in the Grade A share across states. Additional lags of Z and changes of *Premium* were statistically insignificant. Equation (6) 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 (Davidson and MacKinnon 1993, pp. 683–84, 723–25; Greene 1997, pp. 855–56).

As was discussed briefly above, Grade B standards moved closer to Grade A standards over time, thereby reducing the additional cost of meeting Grade A standards and increasing the Grade A share. The time trend in equation (6) is included to capture the effect of the unobserved convergence of Grade A and Grade B standards, as well as other unobserved factors affecting the Grade A share. The short-run effect of the Grade A premium on the log odds ratio of the Grade A share is $(1 - \beta)\gamma_P$. That is, a change in the Grade A premium in year $t - 1$ causes Z to change by $(1 - \beta)\gamma_P \Delta Premium$ in year t. Similarly, the short-run effect of average herd size is $(1 - \beta)\gamma_H$, and the short-run effect of the share of older operators is $(1 - \beta)\gamma_A$. These short-run effects capture variation from the trend in Z caused by changes in *Premium*, *Herd*, and *Age*.

The short-run effects of the Grade A premium, herd size, and the share of older operators accumulate over time because of the persistence in the Grade A share. Dropping the time subscripts and error term from equation (6) and rearranging terms, the long-run equilibrium relationship can be expressed as

$$(7) \qquad Z^*_{it} = \alpha_i/(1 - \beta) + \delta t/(1 - \beta) + \gamma_P Premium^*_i + \gamma_H Herd^*_i + \gamma_A Age^*_i$$

where the asterisk denotes long-run equilibrium values. A unit increase in the Grade A premium raises the long-run equilibrium value of Z by γ_P. Similarly, the long-run effects of herd size and the share 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 (7) to capture the variation in the data across states. Controlling for herd size, and operator age, states with larger Grade A premiums will also have larger equilibrium Grade A shares on average. The error correction model also captures the dynamics within states. If equation (7) defines the long-run equilibrium, the expression in square brackets of equation (6) is a measure of disequilibrium at time $t - 1$. Thus, equation (6) states that the (log odds ratio of the) Grade A share moves toward its equilibrium value at a rate that is proportional to the extent that the actual Grade A share differs from its long-run equilibrium.

To facilitate linear regression, we restate equation (6) as follows:

$$(8) \qquad \Delta Z_{it} = \alpha_i + \delta t + (\beta - 1)Z_{it-1} + \beta_P Premium_{it-1} + \beta_H Herd_{it-1} + \beta_A Age_{it-1} + u_{it}$$

where $\beta_P = (1 - \beta)\gamma_P$, $\beta_H = (1 - \beta)\gamma_H$, and $\beta_A = (1 - \beta)\gamma_A$. Equation (8) is our estimating equation for the Grade A share.

The error correction model depicts how the Grade A share changes in response to deviations from the long-run equilibrium in (7). A negative value for $\beta - 1$ indicates that such an equilibrium exists; the Grade A share rises when it is below its equilibrium level, and falls when it is above its equilibrium level. If

[5] We use a log odds ratio transformation of the Grade A share (others using such a transformation of share data include Griliches 1957; Olmstead and Rhode 2001; and Jarvis 1981). Because the Grade A share for some states in some years is 100%, and since the log odds ratio is undefined at the boundary, we set these observations to shares of 0.99 before calculating the log odds ratio.

$\beta - 1 = 0$, then there is no long-run relationship like (7) because the Grade A share dynamics do not correct deviations from that relationship. This error correction model is appropriate whether or not the data contain unit roots (Greene 1997, pp. 855–56). If the data contain unit roots and $\beta - 1 < 0$, then we interpret (7) as the cointegrating relationship, whereas if the data are mean reverting with $\beta - 1 < 0$, then we interpret (7) as a standard stationary linear regression.

Data

Drawing from U.S. Department of Agriculture, state and federal milk marketing order publications, the Census of Agriculture, and the Census of the Population, we assembled a cross-section time-series data set consisting of state-level data observed annually. The full data set covers forty-seven states, and spans forty-eight years from 1950 through 1997. Table 1 presents brief descriptions and summary statistics for each variable, along with data sources. Here we discuss the data on Grade A shares and Grade A premia. (Balagtas [2004] describes the data in greater detail.)

Panel A of figure 3 plots the Grade A shares for California, Wisconsin, and New York. These are representative of the Grade A shares in all states in that they exhibit a strong tendency toward 100% Grade A. Cross-sectional variation in the Grade A share reflects differences across states in the benefits and costs of producing Grade A milk, relative to Grade B. In our econometric model, the cross-sectional variation in the Grade A premium and other regressors explains variation in the Grade A share.

Casual inspection of the Grade A share data suggests that there are perhaps two stages to the time-series evolution of the series. In the first stage, the Grade A share grows gradually toward 100% Grade A. In the second stage, the Grade A share has reached 100% Grade A and tends to remain there. States nearing 100% Grade A tend to stay near 100% Grade A, perhaps because the investment in Grade A is irreversible, and also because these states may have relatively high Grade A premia. The data in these states reflect a corner solution, and show little or no time-series variation in the Grade A share. Thus, we would expect that states with high Grade A shares are less responsive to marginal changes in the profitability of the Grade A investment. We estimate the econometric models on a subset of thirty states with Grade A shares less than 90% at the start of the data (1950). For comparison, we also estimate the models on the full data set.

Panel B of figure 3 plots the Grade A premium for California, Wisconsin, and New York. The Grade A premium declined over time as the Grade A share rose. As with the Grade A share of milk, the Grade A premium exhibits variation across states. USDA-NASS (a) sometimes does not report the Grade B milk price for states near 100% Grade A. However, because manufactured dairy products are traded across state lines, the price of manufacturing milk is approximately the same for all states, and is highly correlated across states. Moreover, the Federal Milk Marketing Order system has traditionally set the minimum price for manufacturing milk equal to the average Grade B milk price in Minnesota and Wisconsin. Therefore, we use the Grade B price paid in Wisconsin as a proxy for the Grade B price in all states but one. The exception is California, which is regulated by a state marketing order, and for which we use the California Grade B milk price reported by USDA-NASS (a). We use the Producer Price Index for All Farm Products to convert all prices to 1999 dollars.

Estimation and Results

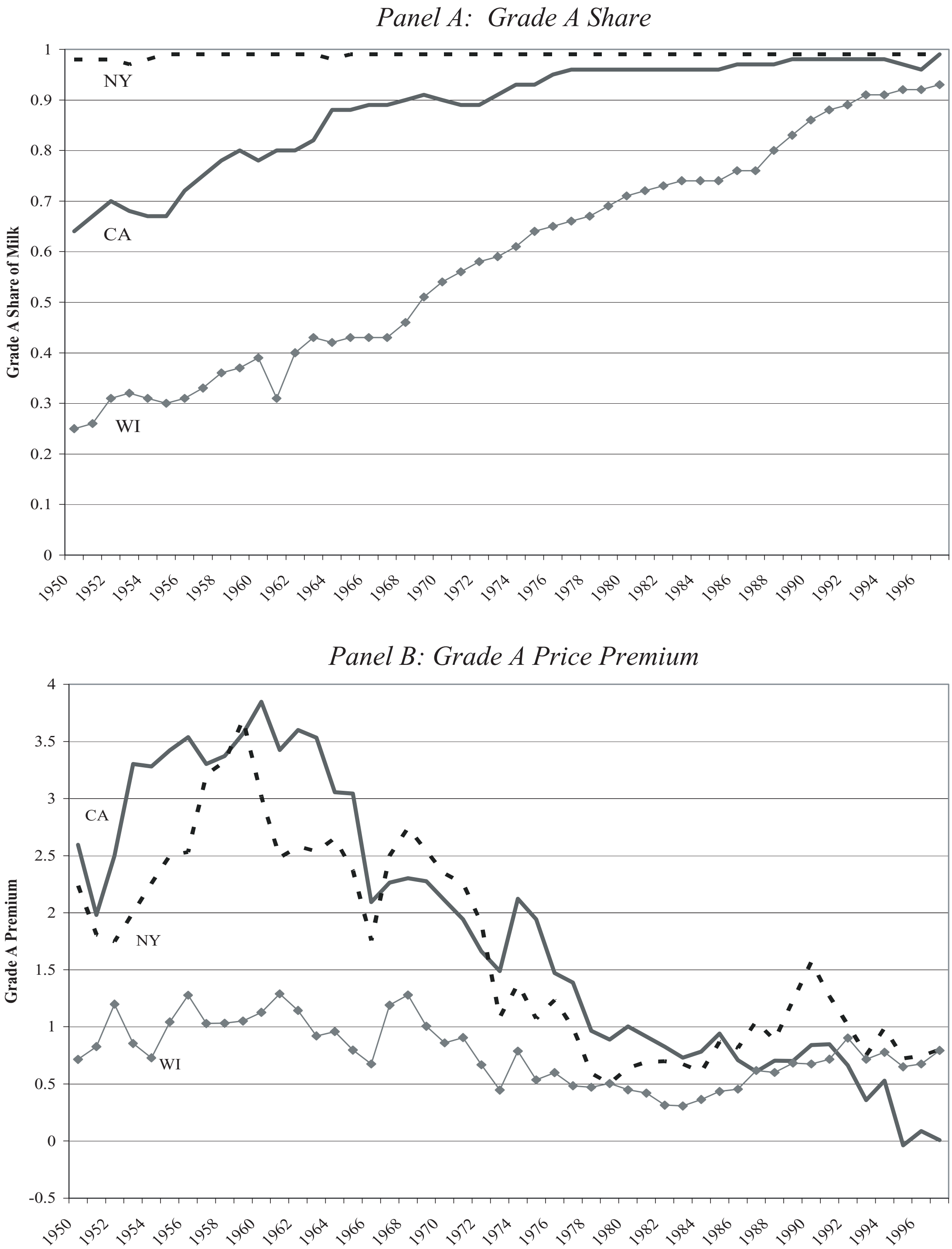
We estimate the Grade A premium regression, equation (3), with generalized least squares (GLS), allowing for correlation across states and state-specific autocorrelated errors. In the top panel of table 2 we report results from the subset of states with initial Grade A shares less than 90% and from the full data set. The coefficient of main interest is the elasticity of the Grade A premium with respect to the fluid milk differential set by marketing orders. For those states with an initial Grade A share of milk less than 90%, the estimated elasticity is 0.644, indicating that a 1% increase in the fluid milk differential results in a 0.64% increase in the Grade A premium *ceteris paribus*. The estimated elasticity for the whole data set is of similar magnitude, 0.653. Thus, we find strong evidence that milk marketing orders are an important determinant of the premium paid for Grade A milk. The Grade A premium is larger where marketing orders set a higher fluid milk differential.

We estimate the Grade A share regression, equation (8), with GLS, allowing for

Table 1. Description of the Data Used in the Analysis, 1,687 Total Observations on Forty-Seven States (Average of Forty Years per State)

Variable	Description	Source	Units	Mean	SD	Min.	Max.
Grade A share of milk	Percentage of milk produced that complies with Grade A standards	USDA-NASS (d)	Share	.832	0.212	0.15	1.0
Log odds ratio[a]	Log of the odds ratio of the Grade A share of milk	USDA-NASS (a)		2.597	1.881	−1.735	4.595
Grade A premium[b,c]	Average price paid for Grade A milk less the average price paid for Grade B milk	USDA-NASS (a)	$/cwt	1.959	1.507	−0.447	7.039
Average herd size[d]	Average number of dairy cows on farms reporting dairy cows	USDA-NASS (c)	100 head	0.404	0.509	0.022	5.295
Operators older than 65[d,e]	Percentage of farm operators older than sixty-five years	USDA-NASS (c)	Share	0.19	0.05	0.08	0.32
Fluid milk differential[b,f]	Difference between the minimum fluid milk price and minimum manufacturing milk price set by marketing orders	USDA-AMS (a), CDFA	$/cwt	2.800	1.237	0.285	8.737
Population	Total population in a state	USDOC	Million people	4.895	4.862	0.322	32.500
Income	Per capita income in a state	USDOC	$ thousand[g]	10.587	5.621	1.637	30.304

[a] Grade A shares of 1.0 are set to 0.99 in order to calculate the log odds ratio.
[b] The average price paid for Grade B milk in Wisconsin is used as a proxy for the Grade B milk price in all states except California. The Grade A premium in California uses the average price for Grade B milk in California.
[c] From the U.S. Census of Agriculture. Inter-census years are interpolated.
[d] Includes operators of nondairy farms.
[e] For most states, we calculate the fluid differential as the simple average differential in all marketing orders regulating milk sold in the state. Minimum prices set by Maine's milk commission have been identical to those set by the FMMO for Boston (Maine Department of Food and Agriculture). We set the Maine fluid differential equal to the fluid differential calculated for Massachusetts. For California, the fluid differential is calculated from regulated prices reported by the California Department of Food and Agriculture. Montana also operates its own marketing order. Montana is omitted from the sample because of a lack of data.
[f] All prices and income are reported in real 1999 dollars, adjusted by the Producer Price Index for All Farm Products.



Source: Authors' calculations based on average prices received by producers for Grade A and Grade B milk (USDA-NASS [a]).

Figure 3. Grade A milk, various states, 1950–1997

heteroscedasticity across states and report the results in the bottom panel of table 2.[6] The key result is that the coefficient on the Grade A premium is positive and statistically significant at the 1% level in both regressions. When the model is estimated on the subset of states with initial Grade A shares less than 90%, the estimated effect of the Grade A premium is 0.026. That is, an additional \$1.00 on the Grade A premium *ceteris paribus* increased the log odds ratio by 0.026 in the first year. To see the effect on the Grade A share, consider a state with an initial Grade A share of 50%. In this case, a \$1.00 increase in the premium increases the Grade A share by approximately 0.65 percentage points, or 1.3%, to 50.65% in the first year.[7] This relatively small short-run effect is to be expected, given the gradual nature of capital replacement on dairy farms. Over time, the cumulative effect is much larger. The long-run effect of the Grade A premium on the log odds ratio of the Grade A share is $\gamma_P = \beta_P/(1-\beta) = 0.026/0.042 = 0.619$. For a state with an initial, long-run equilibrium Grade A share of 50%, a permanent \$1.00 increase in the Grade A premium, raises the Grade A share by 15.0 percentage points to 65.0% $(= e^{0.619}/(1 + e^{0.619}))$.[8]

Using the full data set, the effect of the Grade A premium on the Grade A share remains statistically significant but is also statistically significantly smaller than in the subsample (table 2, bottom panel). Including those states whose initial Grade A shares exceed 90% reduces the average responsiveness of the Grade A share to the Grade A premium and other factors. Producers in states such as New York and New Jersey, who had relatively easy access to large fluid markets, were likely to have sufficient private incentive to produce Grade A milk. Thus, marketing orders have had less of an influence on the milk-grade decisions in these states.[9]

The positive effect of the Grade A premium on the Grade A share, taken together with the result that marketing order regulation is a key determinant of the Grade A premium, is strong evidence in favor of our hypothesis that marketing orders have encouraged the production of Grade A milk. As such, the welfare costs of excess Grade A milk can be attributed, at least in part, to milk marketing orders.

The estimated coefficients on operator age and herd size are statistically insignificant, which suggests that conversion costs (i.e., $k(Q_A)$ in figure 2) associated with herd size and operator age did not strongly affect the Grade A share. Indeed, previous studies found the additional costs of meeting Grade A standards to be small relative the premium created by marketing orders (Cummins 1978; Graf and Jacobson 1973; Frank, Peterson, and Hughes 1977; Bartlett 1964). The premium could exceed the marginal cost of meeting Grade A standards if marketing orders set the fluid milk premium (D) sufficiently high such that all milk produced in a market is Grade A. The positive trend coefficient indicates that the Grade A share tended to increase over time on average for all states, and may be picking up the convergence of Grade A and Grade B standards over time or other factors contributing to lower costs of conversion. However, the significant effect of the Grade A premium on the Grade A share indicates that states where marketing orders set a larger fluid milk differential have larger Grade A shares on average. It also indicates that if a particular state exhibits an above-trend Grade A premium in a particular year, then we expect its Grade A share to increase in future years. Thus, marketing orders were not the sole cause of the increase Grade A shares, but they did cause significantly larger increases in the Grade A share than would have been observed otherwise.

[6] *Premium*, *Herd*, and *Age* appear in equation (8) lagged one period, and thus we take them as predetermined. Nonetheless, we conducted Durbin–Wu–Hausman tests for exogeneity of these variables in case they were determined by expectations of future milk grade choices and therefore were endogenous (e.g., if a farmer expects to convert next year, maybe she would increase herd size this year). We are unable to reject the null hypothesis that *Premium*, *Herd*, and, *Age* are exogenous (Durbin 1954; Hausman 1978; Wu 1973).

[7] From equation (8), $\Delta Z_t = 0.026\Delta Premium_{t-1}$; a \$1-increase in the Grade A premium would cause a short run, 0.026-increase in the log-odds ratio of the Grade A share. Thus, for a state with an initial Grade A share of 50%, $\ln(S_1/(1-S_1)) - \ln(0.5/(1-0.5)) = 0.026$, or $S_1 = e^{0.026}/(1 + e^{0.026}) = 50.65$ (where subscript 1 denotes the Grade A share after the change in the Grade A premium).

[8] The estimated long-run effect of the Grade A premium on the Grade A share is $\gamma_P = 0.619$. For a state with an initial, long-run equilibrium Grade A share of 50%, $\ln(S_1/(1-S_1)) - \ln(0.5/(1-0.5)) = 0.619$, or $S_1 = e^{0.619}/(1 + e^{0.619}) = 65.0$ (where subscript 1 denotes the long-run equilibrium Grade A share after the change in the Grade A premium).

[9] We estimated a model on the full sample, interacting *Premium, Herd, Age,* the lagged dependent variable, and the trend with a dummy = 1 for those states with initial Grade A shares less than 0.9. The effect of the lagged premium is 0.0259 for those states with small initial Grade A shares, compared to 0.0002 for the full sample, and the difference is statistically significant (p-value = 0.00).

Table 2. Regression Results

Grade A Premium Regression (equation 3)

States with initial Grade A share < 0.9

$$\ln Premium_{it} = \underset{(6.58^{*})}{49.248} + \underset{(0.024^{**})}{0.052} \ln Population_{it} + \underset{(0.079)}{0.030} \ln Income_{it} + \underset{(0.028^{*})}{0.644} \ln D_{it} - \underset{(0.003^{*})}{0.025}t$$

Observations = 1,260, states = 30, Wald χ^2 statistic (test of the significance of the regression) = 1,320.4*

Full data set

$$\ln Premium_{it} = \underset{(5.11^{*})}{52.440} + \underset{(0.017)}{0.021} \ln Population_{it} + \underset{(0.058^{**})}{0.131} \ln Income_{it} + \underset{(0.023^{*})}{0.653} \ln D_{it} - \underset{(0.003^{*})}{0.027}t$$

Observations = 1,838, states = 47, Wald χ^2 statistic (test of the significance of the regression) = 1,917.9*

Grade A Share Regression (equation 8)

States with initial Grade A share < 0.9

$$\Delta Z_{it} = \alpha_i^a + \underset{(0.001^{*})}{0.005}t - \underset{(0.007^{*})}{0.042}Z_{it-1} + \underset{(0.006^{*})}{0.026}Premium_{it-1} - \underset{(0.027)}{0.014}Herd_{it-1} + \underset{(0.204)}{0.197}Age_{it-1}$$

Observations =1,282, states = 30, Wald χ^2 statistic (test of the significance of the regression) = 150.1*

Full data set

$$\Delta Z_{it} = \alpha_i^a + \underset{(0.0003^{*})}{0.001}t - \underset{(0.004^{*})}{0.016}Z_{it-1} + \underset{(0.002^{*})}{0.007}Premium_{it-1} - \underset{(0.003)}{0.002}Herd_{it-1} - \underset{(0.080)}{0.049}Age_{it-1}$$

Observations =1,868, states = 47, Wald χ^2 statistic (test of the significance of the regression) = 286.6*

Note: Standard errors are in parentheses.
An asterisk (*) and double asterisks (**) denote statistical significance at the 1% and 5% levels, respectively.
[a] Estimates of state-specific intercepts are jointly significant at the 1% level, but are suppressed to conserve space.

Summary and Implications

Recent work has shown that the extant literature on milk marketing orders is incomplete. Rents created by marketing orders for producers of Grade A milk induce entry into the Grade A market. In particular, farmers who otherwise would have produced Grade B milk switched to Grade A. Moreover, the additional costs incurred by producers to comply with Grade A standards dissipate the policy rents (Balagtas and Sumner 2005).

In this paper, we provide econometric evidence that milk marketing orders were an important cause of the dramatic shift in milk quality toward Grade A milk. We estimate econometric models to explain geographic and temporal variation in the premium paid for Grade A milk and the Grade A share of milk. We find that price discrimination by marketing orders raised the premium paid for Grade A, and the Grade A premium, in turn, resulted in a larger Grade A share of milk. The resulting distortion in the balance between Grade A and Grade B milk, and the implications for the welfare effects of marketing orders, have gone largely unnoticed in the literature.

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