Economic Analysis of the U.S. Fluid Milk Industry

Xiaowei Cai
Department of Agribusiness
California Polytechnic State University
San Luis Obispo, CA 93407
cai@calpoly.edu
Tel: 1-805-756-5011

Kyle W. Stiegert
Department of Agricultural and Applied Economics
University of Wisconsin
Madison, WI 53706
kwstiegert@wisc.edu
Tel: 1-608-263-4176

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Abstract

In the literature, mixed results have been obtained from the studies that have examined the market power of dairy cooperatives and processors. As the main objective of the present work, we intend to find further empirical evidence to investigate whether the dairy cooperatives' oligopoly power that is implicit in the dynamic pricing games exists and how it influences the beverage milk margins from 1983 to 2012. We studied three regional markets: California, New York and Wisconsin. In all regions, we found clear evidence of alternating high- and low-margin regimes during the study years which indicates slight departures from perfect competition in the U.S. fluid milk market. But the levels of departure vary across different states.

1   Introduction

Like many other food processing sectors in the U.S. (e.g., meat, grain, and poultry), the dairy industry has seen significant structural changes and consolidation since 1972 (Ollinger et al. 2005), which originated mainly from technology improvement.Specifically, with dramatically declining number of dairy manufacturing plants and the increasing number of plants operated by the large processors, the four-firm concentration ratio increased from 22% in 1992 to 42.6% in 2002 for fluid milk processing (Shields 2010). The number of dairy cooperatives has significantly reduced to 196 in 2002 from 438 in 1980, however, the dairy cooperatives handled much larger volume of milk and covered larger geographic areas (USDA 2004). In the meanwhile, the total number of dairy farms and farm size have been increasing (USDA 2005).

The fluid milk pricing is influenced by the government regulations as well as the embedded market structure. Unlike other industries, the producer cooperatives in the dairy industry is allowed to use collective action to exercise the oligopoly power under the Federal Milk Marketing Orders (USDA 2004). In the present research, we are addressing the question of how market structural change and government policy work together to impact the market performance.

In the IO literature, many studies have been done to evaluate the dairy cooperative's pricing behavior and their interactions with the upstream and downstream sectors. Kawaguchi, Suzuki and Kaiser (2001), and Cox and Chavas (2001) applied a spatial equilibrium model to the U.S. dairy industry. While the former found modest departures from perfect competition, the latter suggested substantive distortions caused by the marketing order policy. In

addition, static game models have been widely used to evaluate the producer's pricing strat-egy and examine the existence of market power. For example, Merel (2008) measured seller market power in the French Comte cheese market and found no monopoly power exercised during the study years. Prasertsri and Kilmer (2008) investigated the bargaining power of a milk marketing cooperative versus a group of fluid milk processors. They found that the milk cooperative has a relatively much larger bargaining strength than the milk processors. Romain, Doyon and Frigon (2002) examined the fluid milk market in New York city and found the evidence of market power by the middlemen in the market before the launching of price gouging law in the New York state.

So far, the spacial equilibrium model and static game model, a number of prior studies have examined the producer dynamic pricing behavior in U.S. market for fluid milk. For example, Liu, Sun and Kaiser (1995) used an oligopolistic switching regime framework to examine the impact of government price intervention on the dairy processing industry, and they found evidence of more market power with the government support. Hovhannisyan and Gould (2011) investigated the retail market conduct in the U.S. fluid milk industry with a structural model and concluded that retailers behave competitively. Cakir and Balagtas (2012) estimated dairy cooperatives' oligopoly power and they found that the farm milk price is 9% higher than the marginal cost of production due to the dairy cooperatives' market power.

So far, mixing results have been obtained from the studies that have examined the market power of dairy cooperatives, processors and retailers. As the main objective of the present work, we intend to find further empirical evidence to examine if the dairy cooperatives' oligopoly power that is implicit in the dynamic pricing games exists and how it influences the

beverage milk margins during the past 30 years from 1983 to 2012. We studied three regional markets: California, New York and Wisconsin. In all regions, we found clear evidence of alternating high- and low-margin regimes during the study years which indicates slight departures from perfect competition in the U.S. fluid milk market. But the levels of departure vary across different states.

The remainder of the paper is organized as follows. After the theoretic and the empirical model specifications, data are described, followed by empirical results and discussions. The last section concludes.

2 Theoretical Model

The theoretical model is built upon Mailath et al. (2006)'s optimal equilibria with imperfect monitoring. Green and Porter (1984) were the first to introduce the imperfect competition with price uncertainties. Mailath et al. (2006) and Abreu et al. (1986) both extended Green and Porter's work by deriving the optimal collusive equilibria over a broader set of strategies. With the newly improved techniques, identical firms switch between different regimes based on two sets of margins, i.e., high- and low-margin sets.

We assume the dairy cooperatives sell fluid milk to downstream retailers in a repeated game framework. For each individual cooperative, the profit at time t is:

$$\pi(p_t, sp_t, W_t, z_t, \xi_t) = (min\{p_t, sp_t\} - c_t)Q_t(p_t, sp_t, W_t, \xi_t) - pc(z_t, Q_t) \qquad (1)$$

where p_t is the price for the fluid milk sold to the retailers at time t, sp_t is the minimum

support price set by the milk marketing order at time t, c_t is the major feed cost, i.e., soybean meal, corn and hay. W_t is a vector of exogenous variables that affect milk production, Q_t is the milk production quantity, ξ_t is a random term, and pc_t is the processing cost of dairy producers and is a function of z_t, a vector of non-feed variable input prices, and the milk production Q_t.

Given the dairy cooperatives' pricing strategy p_t, and the distribution of the milk supply shock $F(\xi_t)$, each individual cooperative maximizes the sum of current and discounted expected future profits:

$$V(P_t) = \int_0^\infty \pi(p, sp, Q(p, sp, W, \xi), \xi) dF(\xi) \tag{2}$$

For the dairy cooperatives, the milk price offer can be chosen from a finite set of (sp, ∞). So we can only focus on the bang-bang equilibria (Mailath and Samuelson 2006). There exists an optimal symmetric sequential equilibrium where the dairy cooperatives choose a higher price $\bar{p}$ in high-margin regime and the expected value is $\overline{V}$, and they choose a lower price $\underline{p}$ with the expected value of $\underline{V}$. $\overline{V}$ and $\underline{V}$ are the maximum and minimum pure perfect equilibrium payoff for the dairy cooperatives. Switches between the two regimes are determined then by two sets of margins $\overline{m}$ and $\underline{m}$. Therefore, the dairy cooperative's pricing strategies can be described by the following:

$$P_t = \begin{cases} \bar{p} & \text{if } m \in \overline{m} \\ \underline{p} & \text{if } m \in \underline{m} \end{cases} \tag{3}$$

Suppose the conditional probability of margin based on the dairy cooperative's pricing

strategy is $\theta(m|s)$ and the discount rate is r. The dairy cooperative's values in the high- and low-margin regimes are:

$$\overline{V} = (1-r)V(\overline{p}) + r[(1-\theta(\overline{m}|\overline{p}))\overline{V} + \theta(\overline{m}|\overline{p})\underline{V}] \tag{4}$$

$$\underline{V} = (1-r)V(\underline{p}) + r[(1-\theta(\underline{m}|\underline{p}))\overline{V} + \theta(\underline{m}|\underline{p})\underline{V}] \tag{5}$$

The dairy cooperative's equilibrium payoff in the high-margin regime is then given by:

$$\overline{V} = \frac{V(\overline{p})(1 - r\theta(\underline{m}|\underline{p})) + rV(\underline{p})\theta(\overline{m}|\overline{p})}{1 - r(\theta(\underline{m}|\underline{p}) - \theta(\overline{m}|\overline{p}))} \tag{6}$$

In the high-margin regime where dairy cooperatives might exercise oligopoly power, the price offer $\overline{p}$ is higher than the Nash price p^N. In the high-margin regime, any pricing strategy different from $\overline{p}$ is not chosen because of the incentive constraint below:

$$(1-r)(V(p') - V(\overline{p})) \leq r(\theta(\overline{m}|(p')) - \theta(\overline{m}|\overline{p}))(\overline{V} - \underline{V}) \tag{7}$$

where p' is any pricing action different from $\overline{p}$ in the high-margin regime.

In the low-margin regime, $m \in \underline{m}$, dairy cooperatives sell at a low price $\underline{p}$. To sustain a higher payoff in equilibrium, $sp < \underline{p} < p^N$. The optimal pricing strategy in low-margin regime satisfies the following equilibrium condition for any action p' different from $\underline{p}$:

$$(1-r)(V(p') - V(\underline{p})) \leq r(\theta(\underline{m}|p') - \theta(\underline{m}|\underline{p}))(\overline{V} - \underline{V}) \tag{8}$$

Suppose the milk supply shock ξ is randomly drawn from a continuously distribution F on

$[\underline{\xi}, \overline{\xi}]$. $\overline{\xi}$ and $\underline{\xi}$ are the maximum possible shock and the minimum possible shock respectively. Therefore, the cutoff margin set that differentiates between high- and low- margin regimes is $m^c = [0, \tilde{m}]$ for some $\tilde{m} > m^c$, so the payoff to the dairy cooperative by choosing a different price p' than $\overline{p}$ is then:

$$(1-r)V(p', \overline{p}) + r(1 - F(\frac{\tilde{m}}{m(p', \overline{p})}))\overline{V} + rF(\frac{\tilde{m}}{m(p', \overline{p})})\underline{V} \qquad (9)$$

The second order condition of equation (9) is negative based on the assumptions of $\partial^2 V(p', \overline{p})/\partial p^2 < 0$, $\partial m(p', \overline{p})/\partial p' > 0$, and $\frac{\partial^2 m(p', \overline{p})}{\partial p} < 0$, following Cai, Stiegert and Koontz (2011).

Because the payoff function of dairy cooperative concave, any p greater than $\overline{p}$ gives the dairy cooperative the same payoff as $\overline{p}$. We can then infer that any deviations to prices greater than the high-margin price $\overline{p}$ are suboptimal. Deviations toward lower prices do not occur on the optimal equilibrium path. Therefore, the model fits a market condition where lengthy high- and low-margin regimes alternate at the equilibrium.

3   Econometric Model

Based on the theoretic model, an empirical model that allows for regime switching between the high mark-up and low mark-up states is developed. Although margin fluctuates tremendously from one month to the next, the extreme volatility is not all caused by dairy cooperative's market power. In this study, we focus on the potential for disruptions in the supply of fluid milk as a stimulus that drives the regime switching. In particular, when there is

high production, dairy cooperatives might switch from high mark-up to low mark-up states. Meanwhile, not all supply disruptions may lead to a switch in diary cooperative's pricing behavior. Thus, our hypothesis is that when retailers need more milk supply than what can be delivered, dairy cooperatives will become aggressive in selling at a high price. Taking the difference between the milk price and the major feed costs, the dairy cooperative's marketing margin is given by the following equation:

$$m_t = p_t - (p_t^s \times 2.52/2000 + p_t^c \times 22.22/56 + p_t^h \times 25.5/2000) \tag{10}$$

where m_t is the milk margin in \$/cwt at time t, p_t is the milk price in \$/cwt, p_t^s is the price of high-protein soybean meal in \$/ton, p_t^c is the price of corn in \$/bushel, and p_t^h is the price of alfalfa hay in \$/ton. There are various measures to evaluate the relationship between milk price and feed costs, such as the milk-feed ratio, income over feed cost (IOFC) on a per-cow basis, and IOFC based on feed rations. We use the last approach.

Monthly changes in the marketing margin is a recurrent feature of dairy market. Our empirical model will look to evaluate that part of the marketing margin that is not related to marginal costs for potential regime switching behavior. While the actual conduct associated with dairy cooperative's pricing behavior is unobserved, the potential for switching between each regime is modeled using a Multivariate Markov-Switching framework by incorporating the marginal processing cost and the stimulus for regime switching (i.e., the actual milk

production):

$$m_t = \nu_{st} + \beta^s y_t + \gamma_1 w_t + \gamma_2 e_t + \gamma_3 pc_t \tag{11a}$$

$$\nu_{st} = \kappa_1 \xi_t^1 + \kappa_2 \xi_t^2 \tag{11b}$$

$$\varepsilon_t | S_t \sim N(0, \sigma_{st}^2) \text{ where } \sigma_{st}^2 = \rho_1 \xi_t^1 + \rho_2 \xi_t^2 \tag{11c}$$

where m_t is the dairy cooperative's margin level at time t, y_t is actual milk production, w_t is the monthly wage for food processing industry, e_t is the energy and fuel index, pc_t is the packaging cost index, and $S_t = \{1, 2\}$ indicates the 2-state unobserved regimes with $S_t = 1$, representing the low-margin regime and $S_t = 2$, representing the high-margin regime. ν_{st} is the regime dependent intercept and σ_{st}^2 is the error term. The transition between these two states is governed by a first-order Markov process:

$$Prob[S_t = 1 | S_{t-1} = 1] = p \qquad Prob[S_t = 2 | S_{t-1} = 1] = 1 - p \tag{12a}$$

$$Prob[S_t = 2 | S_{t-1} = 2] = q \qquad Prob[S_t = 1 | S_{t-1} = 2] = 1 - q \tag{12b}$$

In the Markov-switching model defined in 11(a)-(c), besides the intercept term ν_{st}, y_t is the only exogenous variable that is subject to switching regimes. All other terms are related to marginal processing costs determined after the feed costs and production quantities are observed. The error terms are assumed to have different variances in the two regimes. Therefore, $(\beta^s, \kappa_1, \kappa_2, \rho_1, \rho_2)$ is the vector of regression coefficients which vary in different regimes, and $\gamma = (\gamma_1, \gamma_2, \gamma_3)$ is the vector of regression coefficients related to milk processing cost and thus stay the same no matter which regime the dairy cooperatives are in.

4   Data and Estimation Results

The dataset used in this analysis includes the monthly industry data of fluid milk prices and production quantities, feed costs, energy, labor and packaging costs in the states of California, Wisconsin and New York which represent the West, Midwest, and East region respectively. In addition, these states were chosen because they represent the most important markets in the U.S. dairy industry. The data are collected from various sources such as Agricultural Marketing Service (USDA-AMS), National Agricultural Statistics Service (USDA-NASS), UW-Madison "understanding the dairy market" extension website, the Department of Energy, and the Department of Labor. The statistics of the variables used in the Markov-switching model is reported in Table 1. As shown in Figures 1 - Figure 3, milk margins in all three states are extremely volatile from month to month. Some of the variations can be explained by wage, energy and packaging costs, and seasonality. And part of the variations could be attributed to the dairy cooperative's oligopoly power and pricing strategy, along with the government regulations.

Essentially, the margin model, when controlling for the processing costs, the supply of milk, allows for alternating high and lower mark-ups over the marginal cost. The sequence of equations was estimated using the Multivariate Markov-switching MLE algorithm developed by Bellone (2005). Our econometric results suggest that dairy cooperatives' margins display the dynamics consistent with the dynamic pricing game. Their margins switch between high- and low-pricing regimes and the underlying economic model suggests this switching does not occur in a competitive market. In all regions, as shown in Table 2, we found statistically significant probabilities of 90% and up that the dairy cooperatives choose high prices when

they price high in the previous period and relatively lower prices when they price lower in the previous period. Therefore, in all regions, dairy cooperatives have more intent to sell high based on the current situation than to sell low. Moreover, the duration of the high mark-up states measures how long the cooperatives can extract rents due to imperfect competition. For California, we find that dairy cooperatives were in high-margin regime 45% of the time. In Wisconsin, dairy cooperatives were gaining high mark-ups around 25% of the time over the thirty years and in New York, cooperatives were selling at high prices 31% of the period examined. Therefore, California has the longest high-margin duration among the three states. Wisconsin and New York have similar duration. This could be attributed to the different milk marketing orders under which the milk markets in these three states are regulated. Wisconsin and New York are regulated under the Federal Milk Marketing Order, while California has its own state Milk Marketing Order. The results provide some evidence that non-competitive market conduct could have existed in the three regional beverage milk markets from 1983 to 2012, which is consistent with what was found in Kawaguchi, Suzuki and Kaiser (1997) that the U.S. interregional milk markets are characterized by small degree of non-perfect competition.

Also shown in Table 2, in all regions, the regime-switching parameter β is highly statistically significant and is negative. This result confirms our previous hypothesis that when supply is small, the dairy cooperatives will price more aggressively (i.e., higher) which leads to higher margins. And when there is lots of supply, the dairy cooperative's margin would decrease. This is especially true in the markets with relatively more inelastic demand (Cox and Chavas 2001), in our analysis, the California market.

Figures 4-6 show the inferred probabilities that the dairy cooperatives in the three re-

gional markets are in the high-margin state ($S_t = 2$) at time t based on the available information at that time P[S_t=2|ε_t, ε_{t-1},...]. Following Hamilton (1989), our decision rule is that dairy cooperatives are in a high-margin regime when P[$S_t = 2$] > 0.5. In all three markets, the dairy cooperatives are earning high margins from early 1983 to early 1988. During that time, the dairy industry was supported by the price support program, import quotas and milk marketing orders. However, by the mid-1980s, price supports gradually reduced and trade agreement was renegotiated under GATT in 1986 (Chouinard et al. 2010). Since then, the market outcomes in the dairy industry has been mainly influenced by the Federal or State Milk Marketing Orders. New York and Wisconsin have similar switching patterns. The high-margin regimes were seen from late 1989 to late 1990, and again from mid-1998 to early 1999. Difference from New York and Wisconsin, California has seen more regimes with high margins, from mid-1989 to early 1990 , from 1996 to 1997, from 1998 to late 2001, from late 2003 to late 2005, and from early 2007 to early 2008.

From the inferred probabilities of the high-margin regime, we calculated the average margin levels in the two distinct regimes for all three regions and reported them in Table 3. Californian dairy cooperatives have an average margin of \$11.35/cwt in the high mark-up regime, while New York and Wisconsin dairy cooperatives have rather similar average margins of \$14.82/cwt and \$14.75/cwt respectively. In the low mark-up regime, the dairy cooperatives in California earn \$8.50/cwt on average. Those in New York and Wisconsin earn \$10.39/cwt and \$10.69/cwt respectively in the low margin regime. During the high-margin (low-margin) regime, the milk supply is correspondingly low (high). Moreover, we conducted the test for each region to examine the significance of the margin discrepancy between the two regimes. Interestingly we find that the difference in California is not statistically significant,

but the difference in New York and Wisconsin is significant at the 90% significance level. Although California has the longest high-margin duration among the three studied states, the difference between the margin values in the two regimes is the smallest. The other two states have very similar regime switching pattern. This could again be resulted from the different marketing orders implemented in these states.

Further, we find that, consistent with the empirical implications about the effect of federal support (Liu, Sun and Kaiser 1995; Cakir and Balagtas 2012) on dairy market performance, with the federal marketing orders, dairy cooperatives are more able to enter into the high mark-up phases. However, the high margin regime is harder to maintain because competitive pricing on beverage milk is more easily seen and the oligopoly reverts to competitive pricing behavior more readily. But this switching conduct varies across the markets.

5   Conclusion

In this paper, we apply the Multivariate Markov-switching model to the U.S. fluid milk industry. The monthly margin between milk price and feed costs is modeled and the unobserved pricing strategy by the dairy cooperatives in the three regional fluid milk markets is analyzed. The results at the regional markets suggest varied levels of high- and low-margin regimes exist in the last 30 years from 1983 to 2012.

In all regions, dairy cooperatives have more intent to sell high based on the current situation than to charge low. We find in California, dairy cooperatives were in high-margin regime 45% of the time. While in New York and Wisconsin, dairy cooperatives were extracting high mark-ups around 25% and 31% of the period examined. The inference of probability of dairy

cooperatives being in the two regimes is also calculated. Californian dairy cooperatives have more frequent regime-switching activities, compared to the dairy cooperatives in New York and Wisconsin. Moderate deviations from perfect competition have been observed in all three regions.

Furthermore, it is found that high (low) margin is correlated with low (high) milk supply in all regions. The average margins in both regimes are lowest and the difference between the margins is statistically insignificant in California. The average margins are very similar in New York and Wisconsin and the margin level in the high mark-up regime is statistically greater than that in the low mark-up regime. Although some evidence of dairy cooperative's oligopoly power exists, the conduct varies across regions. Future research will focus on an overall assessment of the competitiveness impact of the federal marketing orders. It requires a more innovative combination of measures from the empirical methods and potentially other information such as dairy cooperatives' total costs of production to make a conclusive determination as to the impact.

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Table 1: Descriptive Statistics for the Three Regional Milk Markets

Variable	obs.	mean	s.d.	min	max
California					
Milk Margin ($/cwt)	350	9.84	2.57	3.33	15.73
Milk Production (million lbs)	350	2367.37	744.65	1074	3675
New York					
Milk Margin ($/cwt)	350	11.59	2.63	4.89	17.45
Milk Production (million lbs)	350	982.51	56.68	847	1134
Wisconsin					
Milk Margin ($/cwt)	350	11.65	2.46	5.11	17.25
Milk Production (million lbs)	350	1969.64	135.55	1638	2320
Monthly Wage	350	614.41	23.15	551.99	669.80
Energy Index	350	116.14	26.67	67.80	201.42
Packaging Index	350	154.14	7.64	138.48	178.66

Note: all the dollar amounts are deflated in $ in January of 2000.

Table 2: Estimates of Markov Regime Switching Model

	Parameters	California		New York		Wisconsin	
		estimate	s.d.	estimate	s.d.	estimate	s.d.
Regime-Independent Estimator	γ_1	0.059***	(0.020)	-0.024	(0.025)	-3.205	(0.975)
	γ_2	-0.049	(0.036)	-0.267***	(0.040)	-1.493***	(0.530)
	γ_3	0.322***	(0.023)	0.529***	(0.031)	2.999***	(0.875)
Regime Dependent Estimator	p	0.968***	(0.013)	0.988***	(0.007)	0.983***	(0.008)
	q	0.965***	(0.014)	0.973***	(0.017)	0.950***	(0.024)
	β_1	-0.698***	(0.034)	-0.322***	(0.033)	-0.355***	(0.047)
	β_2	-0.729***	(0.037)	-0.291***	(0.045)	-0.259***	(0.030)
	κ_1	-0.415***	(0.002)	-0.339***	(0.030)	-0.358***	(0.043)
	κ_2	0.451***	(0.036)	0.921***	(0.053)	1.110***	(0.035)
	σ_1	0.066***	(0.007)	0.173***	(0.018)	0.442***	(0.013)
	σ_2	0.168***	(0.019)	0.144***	(0.028)	0.071***	(0.033)
Expected Duration	Low Margin	55%		69%		75%	
	High Margin	45%		31%		25%	

*** $p < 0.01$

Table 3: Average Margin Results for the Two Regimes.

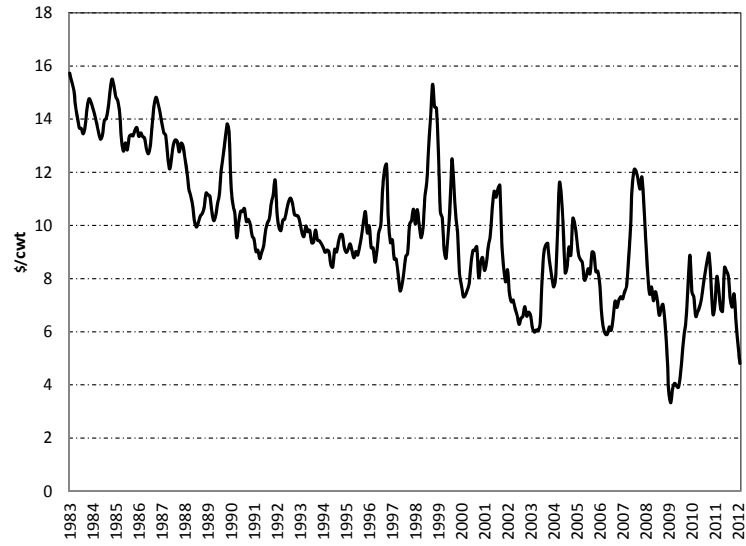| Variables	California	New York	Wisconsin
High Margin	$11.35/cwt	$14.82/cwt	$14.73/cwt
Low Margin	$8.50/cwt	$10.39/cwt	$10.69/cwt
Difference	$2.85/cwt	$4.43*/cwt	$4.04*/cwt

* $p < 0.10$

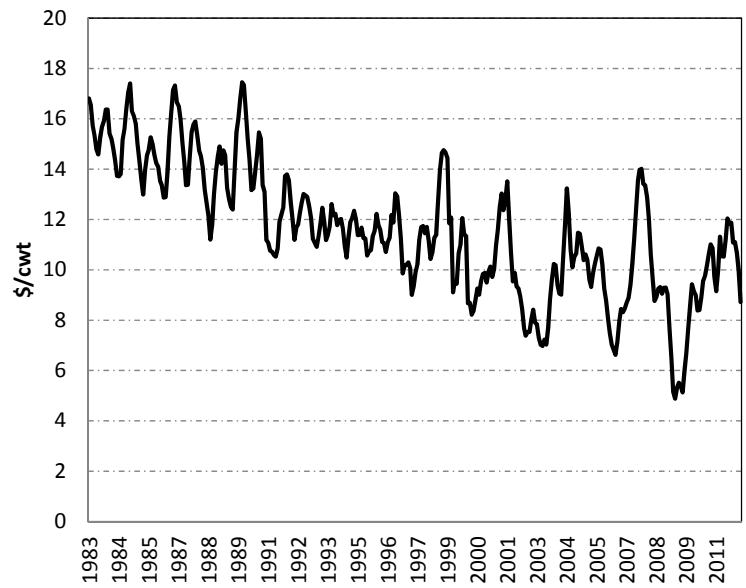Figure 1: Fluid Milk Margins in California during January 1983 – February 2012.

Figure 2: Fluid Milk Margins in New York during January 1983 – February 2012.
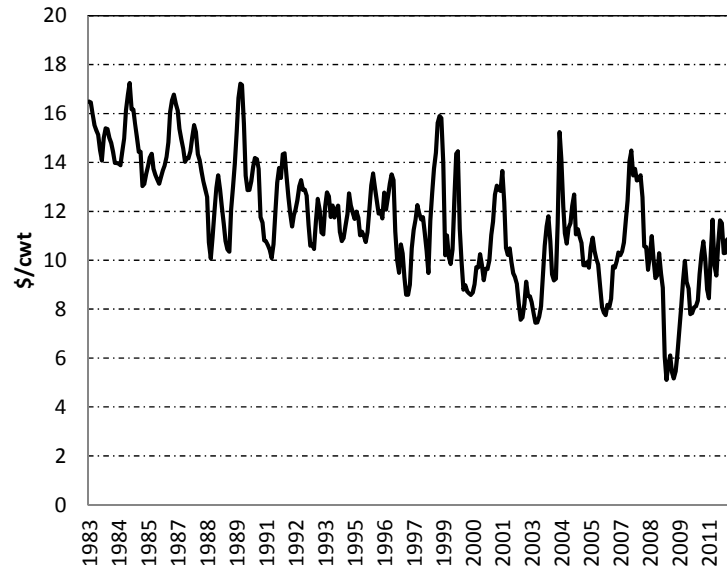
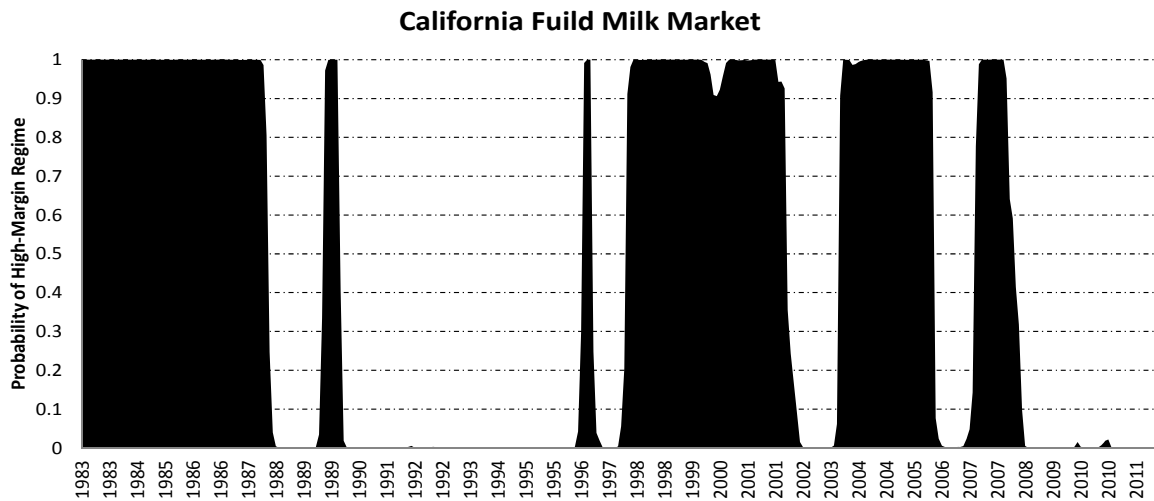Figure 3: Fluid Milk Margins in Wisconsin during January 1983 – February 2012.

Figure 4: Probability of High-Margin Regime in California, January 1983 – February 2012.
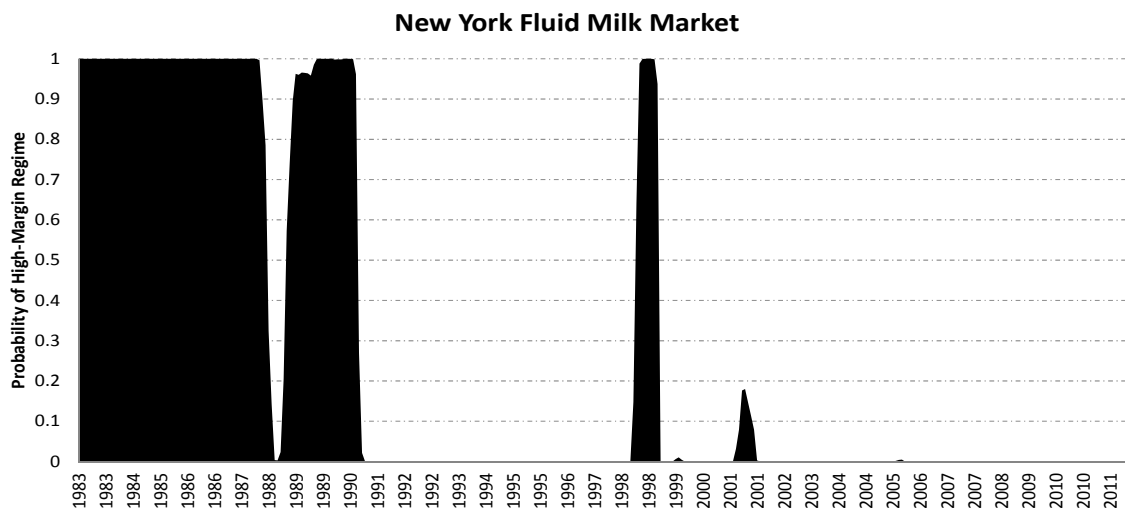
New York Fluid Milk Market

Figure 5: Probability of High-Margin Regime in New York, January 1983 – February 2012.
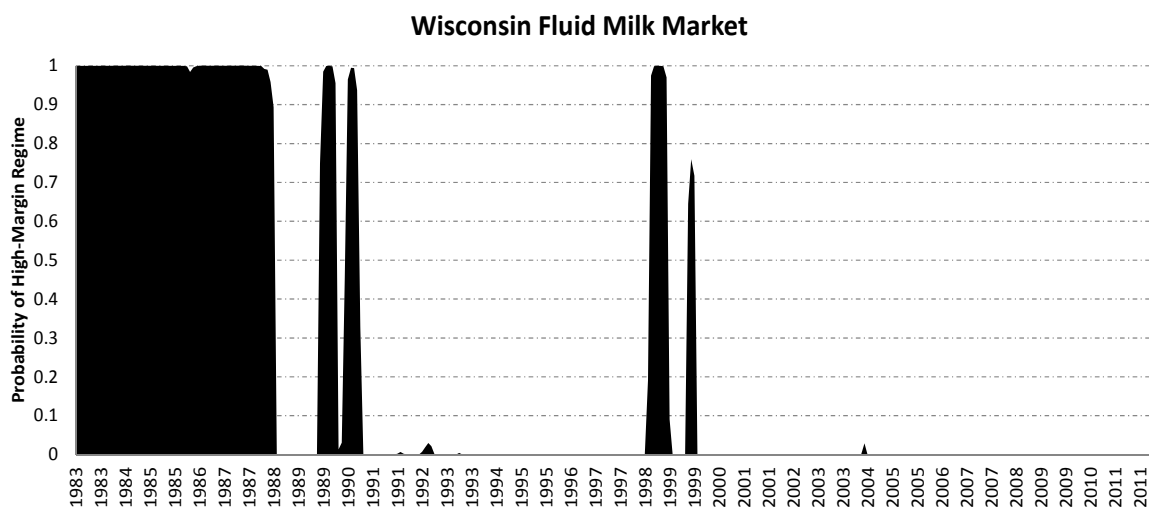
Wisconsin Fluid Milk Market

Figure 6: Probability of High-Margin Regime in Wisconsin, January 1983 – February 2012.