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Road Block to Risk Management - How Federal Milk Pricing Provisions Complicate Class 1 Cross-Hedging Incentives

Abstract

In 2000 the USDA introduced new methods to price milk used to produce class 1 beverage milk in the U.S. This shift in the dairy policy complicated hedging incentives by exposing traders to basis risk and increasing milk price uncertainty. We use empirical analysis to compute generalized optimal hedge ratios and estimate autoregressive models to forecast the basis associated with cross-hedging class 1 milk using exchange traded milk futures. The results indicate that while milk futures contracts do provide risk management opportunities for cash market participants, market participants are trading price risk for highly variable basis risk. Exchange traded milk futures contracts only capture a portion of the variance in the beverage milk cash price, the closing basis fails to converge to some predictable level, and for risk-averse agents basis reduces the utility gained from hedging. Policy and market options may be considered to improve risk management in the beverage milk sector. These options include: allow forward contracting in class 1 milk, alternative price discovery methods, and the introduction of an exchange traded fluid milk contract.

Keywords: class 1 milk, dairy prices, hedge fluid milk, basis risk, FMMO

Introduction

Milk production in the United States (U.S.) is approaching 200 billion pounds per year, of which, approximately one-third flows into packaged fluid milk products (class 1 beverage milk) and two-thirds flows into soft and hard manufactured products (U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS)). A majority of the milk marketed by dairy farmers across the nation is priced through Federal Milk Marketing Orders (FMMOs). These marketing orders guarantee a minimum cash price received by dairy farmers for their milk using revenue pooling and end-product price formulas, but do not protect against variability in the cash price. Since FMMOs enforce minimum price provisions, risk management through forward contracts on class 1 beverage milk is prohibited by law. As a result, the most common method to protect against price variability is to cross-hedge using exchange traded futures contracts. Cross-hedging is generally thought to be effective provided basis risk is minimal and less than price risk. However, this is not always the case with class 1 milk as cross-hedging is subject to periods of excessive basis risk because milk futures cannot replicate the price dynamics inherent in the class 1 end-product pricing formula.[1] (Basis is the difference between the cash and futures market price upon liquidation of the futures position.) Exposure to basis results in financial gains or losses, makes it difficult to construct marketing plans, and may discourage future cross-hedging endeavors. Consequently, Federal milk pricing provisions inhibit the ability to shift or manage the price risk for approximately 55 billion pounds of milk produced and sold in beverage form in the US each year. Fluid milk market participants are thus at a pricing disadvantage compared to their manufacturing counterparts because there is no opportunity to directly manage their future milk price.

The price variability of milk markets is well established in the literature as early analyses of dairy risk management using dairy futures contracts include Fortenbery et al. (1997) and Anderson et al. (1999). Fortenbery et al. found a strong relationship between the futures market and the cash price which supported hedging as a risk management strategy. Anderson et al. noted that the successfulness of the hedging strategy is contingent on the predictability of the closing basis. More recent work by Maynard and Bamba (2004), and Maynard et al. (2005) found that the length of the hedge was a successful component of eliminating the cash price risk in mailbox milk prices, and that hedging using futures markets can eliminate 50 to 60 percent of the cash price variation when using more distant milk delivery contracts. This early literature, however, only characterized the effectiveness of hedging the cash price risk associated with the mailbox milk price. (The mailbox price represents the net pay price received by dairy farmers for milk and includes premiums and authorized deductions.) Using the mailbox price does not capture the cash price risk realized by fluid market participants. Zylstra et al. (2004) recognized the basis exposure associated with shorting class 1 milk using milk futures and concluded that Federal milk pricing provisions lead to volatility in the closing basis and prevented hedgers from locking in a minimum price. With recent price volatility in class 1 milk markets, there is a need to examine how Federal milk price provisions impact the effectiveness of different risk management strategies.

The purpose of this paper is to identify the Federal milk pricing provisions that are the sources of basis risk when cross-hedging class 1 milk. We will then measure the basis over the past decade using empirical data to determine the effectiveness of different cross-hedging strategies. The generalized optimal hedge ratio (Myers and Thompson, 1989) is then estimated using ordinary least squares regression, and finally autoregressive models are used to characterize historical price behavior and predict future values of basis.

The contributions of this work relative to prior literature: (1) extends the characterization of basis to include alternative cross-hedging strategies; (2) we use the constant relative risk aversion (CRRA) utility framework to identify agent preferences towards basis risk; (3) we present price relationships inherent in the basis and FMMO class prices which show that cash price risk cannot be easily minimized; (4) we use empirical data to estimate the generalized hedge ratio under different hedging strategies; and (5) we show that prediction algorithms

[1] For a glossary of terms used in the futures industry see the CFTC glossary available online at: www.cftc.gov

fail to accurately foreshadow basis variability.

Our efforts indicate that exchange traded futures contracts may provide risk management opportunities for cash market participants, but the participants should use caution because milk futures contracts: (1) only capture a portion of the movements in the cash price, (2) the closing basis does not converge to some predictable level (e.g. Purcell and Hudson, 1985; Bollman et al., 2003), and (3) for risk averse agents, uncertainty in the milk price due to basis may have negative effects on utility. We find that the basis exposure is traceable to price dynamics incorporated into end-product pricing formulas during FMMO reform. As a result, fluid milk market participants are unable to use risk management tools to directly, and accurately, manage their cash price risk.

The paper is organized as follows: in section 1 we will provide a primer on milk pricing and policy in the U.S. In section 2 we demonstrate how to develop a class 1 milk cross-hedge using Chicago Mercantile Exchange (CME) futures contracts, and construct the utility framework associated with the buying and selling of class 1 milk. Section 3 provides basis summary statistics. Section 4 measures the generalized optimal hedge ratio and section 5 explores the goodness of fit for autoregressive linear prediction models. Section 6 considers the policy implications of the analysis and section 7 concludes the paper.

1 Milk Pricing and Policy

Approximately 60% of the milk marketed by dairy farmers across the nation is priced through FMMOs (USDA). These marketing orders provide a complex set of regulations designed to facilitate the orderly marketing of milk by guaranteeing a minimum cash price received by dairy farmers for their milk. The initial expectation with FMMOs, when they were approved in 1937, was to equalize competition between fluid milk processors and producers by promoting to some degree the stability in prices and marketing relationships. The Federal support price program of 1949 enforced minimum pricing to dairy producers, ensuring that beverage milk processors could not exercise their market power to drive down the milk price. The minimum price protection from the 30's and 40's through the present has remained virtually unchanged. A minor change in the FMMO language in 2008 by USDA allowed producers to voluntarily circumvent minimum pricing provisions using forward price contracts for milk deliveries into manufacturing classes only. These privileges were not extended to milk marketed to fluid milk plants. Fluid milk processors remain subject to minimum price enforcement based on their utilization of raw milk.

These FMMO pricing provisions, while providing for a minimum price, do not protect those in the dairy industry from significant volatility in their cash price when they buy or sell fluid milk. For example, the class 1 base price of milk, a measure of the milk price paid by beverage milk processors, averaged \$18.14 per hundredweight (cwt) in 2007. This price dropped by 37% in 2009 to \$11.48 per cwt and then rebounded 67% to \$19.13 per cwt in 2011 (see figure 1).

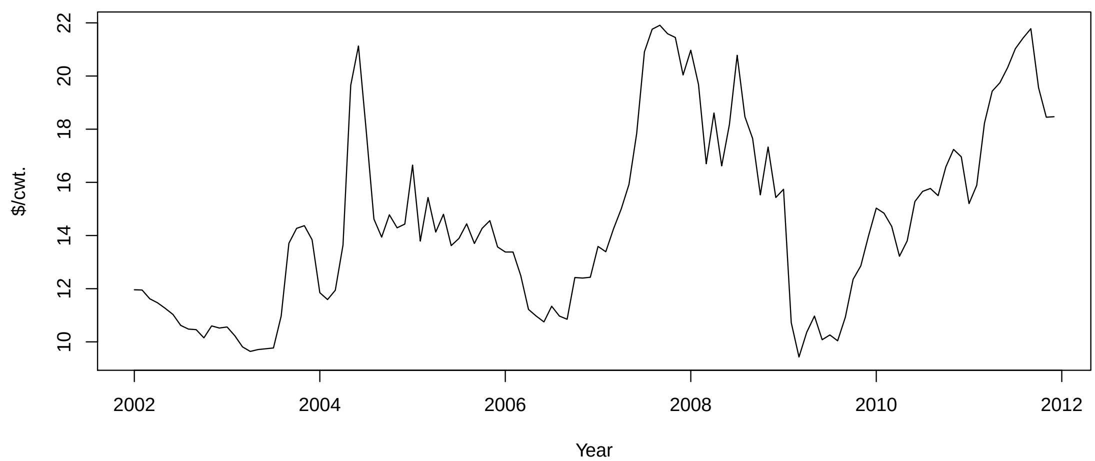

Figure 1: Class 1 Base Milk Price, 2002 - 2011. Does not include fixed location differential.

The industry first responded to the need for risk management tools in 1993 when the Coffee, Sugar and Cocoa Exchange (CSCE) launched futures contracts for cheddar cheese and non-fat dry milk. The thought was that correlation between the commodity prices and raw milk prices would facilitate hedging activity by dairy industry participants (Fortenbery et al., 1997). The lack of trading activity by fluid market participants lead the CSCE and the CME to petition the Commodity Futures Trading Commission to begin trading a futures contract in fluid milk in 1995. By 1996 fluid milk futures were introduced on both the CSCE and the CME.

The fluid milk futures contract was a cash-settled derivative instrument for the Basic Formula Price (BFP). The BFP was a synthetic price reported monthly by NASS. It was composed of two parts: a survey estimate of grade B manufacturing milk prices and a price adjuster based on changes in manufactured dairy product prices between the previous and current month (Machester et al., 2001). Since the BFP was used by the USDA to establish minimum milk prices throughout the country, fluid milk futures proved to be an effective tool to manage price risk. The fluid milk contract was effective for buyers and sellers of class 1 milk because FMMO pricing directly incorporated the BFP, and cash market participants could accurately relate their prices to the BFP contract price. The most direct hedging opportunity with the BFP was for beverage milk pricing because the monthly class 1 price was the BFP price from two months earlier plus a fixed location adjustment (Fortenbery et al., 1997; Jesse and Cropp, 1997). Hedging using the BFP did not expose the trader to basis risk because it settled to the USDA announced price.

The ease to which buyers and sellers of fluid milk could engage in hedging activities stopped in 2000 when the USDA, at the request of producer groups and their cooperatives, replaced the BFP with end-product pricing formulas for each of the four classes of milk.[2] The price classifications are: class 1 for beverage milk; class 2 for soft dairy products like ice cream and yogurt; class 3 for cheese; and class 4 for butter and powder. The methodology for determining the fluid milk price also changed dramatically. The fluid milk price was no longer based on a lagged manufacturing price; instead the price was the higher of two separate advanced pricing factors (referred to as the class 1 mover). Allowing the class 1 mover to alternate among the highest valued manufacturing classes of milk each month increased the minimum price received by dairy farmers marketing milk through FMMOs. In response to FMMO reform the CME discontinued BFP futures and began offering futures contracts for manufacturing milk only (class 3 and class 4 futures). This shift in pricing policies complicated hedging incentives and basis calculations.

The CME has yet to adopt a fluid milk contract. Instead the CME offers spot, futures, and options contracts on a variety of products including class 3 and 4 milk, cheese, butter, non-fat dry milk, whey and international skim milk powder. These products are not sufficient to directly manage class 1 price risk because they give rise to the advance and mover effects on basis that are a byproduct of the class 1 fluid milk pricing formula implemented during FMMO reform. The advance effect is the result of a 1 to 2 week difference between the announcement of the class 1 mover price and the expiration date of the underlying CME futures contract. The mover effect is the result of the class 1 price being derived from the maximum of the class 3 and class 4 advanced pricing factors each month. Zylstra et al. recognized that these effects lead to volatility in the closing basis preventing class 1 hedgers from locking in a minimum price.

Both buyers and sellers of fluid milk would like to manage price risk through forward price contracts; however, unlike their manufacturing counterparts, there is no opportunity to forward contract because FMMOs enforce minimum pricing provisions on only class 1 beverage milk.[3] Prices below the minimum price, even if agreed upon in a forward contract, undermine the regulatory provisions of FMMOs and are not permitted. Fluid milk buyers and sellers can go to over-the-counter swap markets to lay off their risk; however, concerns about FMMO minimum price enforcement, counter-party risk, the lack of margin accounts, and no regulatory oversight make over-the-counter swaps a less than ideal risk management platform. As a result, participants in the fluid milk market whose financial interests can represent well over ten billion dollars have limited options to adequately manage their milk price risk (Dean Foods Company, Annual Report, 2010).

[2]Price formulas can be found online at: www.ams.usda.gov/dairy

[3]FMMO language §1000.73 of the Code of Federal Regulations allows for minimum price deductions authorized in writing. Deductions common in the industry include transportation fees, advertising and promotion fees, and loan fees. The Agricultural Marketing Agreement Act of 1937 allows for minimum price adjustments for volume, market and production differentials customarily applied by the handlers subject to such order, the grade or quality of the milk purchased, and the locations at which delivery of such milk, or any use classification thereof, is made to such handlers.

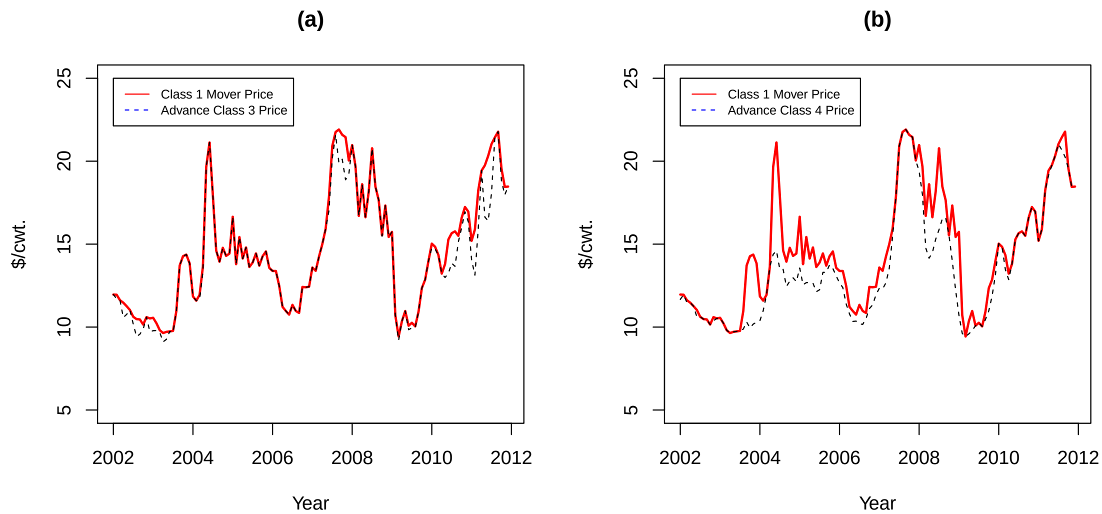

Figure 2: The Advanced Class 1 Mover, 2002 - 2011. (a) Advanced class 1 mover and the class 3 advanced pricing factor, (b) Advanced class 1 mover and the class 4 advanced pricing factor.

2 Cross-Hedging Class 1 Milk

Milk pricing in the US employs a classified pricing system and product price formulas to price milk depending on its end-use. Product price formulas use weighted average commodity prices for cheese, butter, non-fat dry milk and whey to price milk in each class.[4] The prices of interest in this analysis are the advanced class 1 mover, the advanced pricing factors for class 3 and class 4, and CME class 3 and 4 futures prices. (Futures contracts are derivatives of the final USDA announced class 3 and 4 prices). Figure 2 shows the class 1 mover and the class 3 and class 4 advanced pricing factors from 2002-2011.

The advance and final class 3 prices are based on cheese, whey and butter commodity prices announced by NASS. The advance and final class 4 prices are based on butter and non-fat dry milk commodity prices announced by NASS. The formulas used for the advanced pricing factors and the final prices are the same within each class, the only difference between the prices is that the advanced price is calculated using the weighted average of the two most recent weeks of NASS dairy product price and sales data prior to the 23rd of the month and the final price is calculated using the weighted average of the four or five most recent weeks of NASS dairy product price and sales data prior to the 5th of the following month (see table 1). [5]

[4]For a more detailed exposition on FMMO classified pricing see Thraen, 2006, or visit: www.ams.usda.gov/dairy

[5]Beginning in April 2012 Agricultural Marketing Service assumed dairy product price and sales reporting duties from NASS, and the price announcement dates switched to Wednesday

Table 1: Sample Release Dates for Federal Milk Order Prices

Month	Class Price	Announcement Date	NASS Survey Prices Used
Dec 2011	Advance CL 3 & 4	Nov 18, 2011	11/5, 11/12
Nov 2011	Final CL 3 & 4	Dec 2, 2011	11/5, 11/12, 11/19, 11/26
Dec 2011	Final CL 3 & 4	Dec 30, 2011	12/3, 12/10, 12/17, 12/24

The class 1 milk price is comprised of the advanced class 1 mover price plus a fixed location differential. The class 1 mover alternates among the highest of the advanced class 3 and the advanced class 4 milk pricing factors each month, and is announced on a Friday on or before the 23rd of the month. The class 1 mover price is used to price milk purchased in the following month (i.e. the price for class 1 milk bought and sold in December is announced on or before the 23rd of November). The only source of variation in the class 1 milk price is in the mover because the class 1 price location differential is fixed.

Since the class 1 milk price is announced using data from the month prior, and no class 1 futures exist, the overlap in survey price and sales data between the advance and final prices (e.g. table 1) allows for CME class 3 and 4 futures contracts for the delivery month prior to the month fluid milk is purchased to be used to form a cross-hedge. A cross-hedge involves taking a position in an asset with similar price movements as the hedged asset and helps to reduce the financial risk associated with the cash market position (Anderson and Danthine, 1981). For example, to hedge the risk associated with purchasing class 1 fluid milk in December the trader must use either a November class 3 futures contract, class 4 futures contract, or some combination of the two. The trader must use the November futures contracts because the December class 1 price will be derived from the highest of the class 3 or 4 advanced pricing factors which are calculated using November survey data.

As an example consider a plant manager who wants to cross-hedge the July 2007 milk price in January 2007 (six months prior to milk being received). In January the manager goes long using the June 2007 class 4 futures contract at \$14.00 per cwt (excluding transaction costs). On June 22, 2007 when the class 1 mover price is announced the manager liquidates the futures position at a market price of \$19.80 per cwt. The return from hedging has netted the manager \$5.80 per cwt. Once the milk is received the manager must pay the class 1 cash price of \$20.91 per cwt to the producer and the government (FMMO pool).[6] Even though the CME contract netted \$5.80, the basis of \$1.11 (\$20.91 - \$19.80) made the effective cash price \$15.11 per cwt compared to the cross-hedged position of \$14.00. So rather than locking in a \$14.00 milk cost, the actual price was \$15.11.

For this analysis, basis is given by the following formula: $b_t^i = S_t - F_t^i$, for $i = 3, 4$. The term b_t^i represents the closing basis for contract i and month t, S_t represents the class 1 mover at time t, and F_t^i represents the underlying futures class 3 or 4 settlement price at time t.

[6] Regulated class 1 buyers of milk must account to a FMMO pool the difference between the use value of the milk at the plant and the market weighted average blend price.

The importance of the basis can be evaluated using the CRRA utility framework. The CRRA utility function is given by: $U(\pi) = \frac{\pi^{1-\sigma}}{(1-\sigma)}$, where π is an economic variable capturing the returns from buying (B) or selling (S) milk for each representative agent (assuming no transaction costs), and σ is a measure of the degree of risk aversion ($\sigma > 0$ and $\sigma \neq 1$). Higher values of σ indicate higher levels of risk aversion and provide more curvature to the utility function. Since $U(\pi)$ is monotonically increasing in π higher values of π increase agent utility.

For a buyer of class 1 milk π^B can be expressed as the difference between the output price (P_t) and the purchase price (C_t) for the fluid milk: $\pi_t^B = P_t - C_t$. The purchase price for the milk is defined as the spot price of milk less the gains from hedging: $C_t = S_t - (F_t^i - F_0^i)$, where F_0^i is the class 3 or 4 locked-in futures price. Using the formula for the basis we see that $C_t = F_0^i + b_t^i$; which yields: $\pi_t^B = P_t - F_0^i - b_t^i$. Applying this result we see that higher basis increases the purchase price for milk and reduces π^B. This is also demonstrated when evaluating the first derivative of $U(\pi^B)$ with respect to b_t^i (i.e., $\frac{\partial U(\pi^B)}{\partial b_t^i} < 0$).

For a seller of class 1 milk π^S is be defined as the price of milk sold (C_t) less the cost of production (K_t) such that: $\pi_t^S = F_0^i + b_t^i - K_t$. The price for the milk received increases with the basis. Higher basis increases the seller's utility, and is confirmed when evaluating the first derivative of $U(\pi^S)$ with respect to b_t^i (i.e., $\frac{\partial U(\pi^S)}{\partial b_t^i} > 0$).

Based on the expected utility framework we see that positive (negative) basis reduces (increases) the utility for the class 1 buyer and increases (decreases) the utility for the seller of class 1 milk. The unpredictable nature of the basis adds uncertainty to the representative agents utility and can discourage cross-hedging endeavors.

Since class 3 and 4 futures prices often alternate back and forth as to which is the highest in a given month it is difficult to formulate an efficient hedging strategy that maximizes utility by minimizing the negative effects of basis. Over the last decade the class 3 price has served as the mover 61% of the time while the class 4 price has served as the mover 39% of the time. In the following section we will observe the effect of milk pricing provisions (i.e. the higher-of and advance effect) on basis under different risk management strategies.

3 Measuring Basis

In order to analyze the basis associated with class 1 cross-hedging there were four scenarios estimated for the ten year period of January 2002 to December 2011[7]: (1) Ex-post analysis using the contract underlying the class 1 mover (ex-post basis); (2) pure-strategy using the class 3 contract to cross-hedge class 1 milk (class 3 basis); (3) pure-strategy using the class 4 contract to cross-hedge class 1 milk (class 4 basis); and (4) a strategy using the highest valued contract (F^{max}) 90 days prior to the class 1 price announcement (90-day basis).[8]

[7] All basis measurements were calculated at 3.5% butterfat to correspond with USDA announced prices.

[8] Where applicable for months when the futures contract did not have a reported value within 90 days of expiration the price from trading day closest to 90 days was used.

The strategy using the highest valued contract 90 days to maturity has foundation in the literature (e.g. Bozic, 2011; Maynard et al., 2005). Bozic identified a mean prediction error in class 3 futures of 2.7% at 30 days to maturity. At 90 days to maturity a prediction error of 14.20% for class 3 futures was identified. Maynard et al. found that longer hedging intervals could eliminate up to 60% of the cash price risk. Since futures contracts are settled against a known formula which is revealed up to 3 weeks prior to contract maturity a 30 day cross-hedge window would have been too small to offer significant price protection to the trader. 90 days provides the potential for significant changes in the futures contract value, thereby providing hedging opportunities to the trader.

The volatility in the closing basis for each of the hedging strategies is demonstrated in figure 4. As demonstrated the ex-post basis showed the least amount of variation, followed by the 90-day basis, the class 3 basis, while the class 4 basis showed the most volatility. The ex-post basis is calculated after all uncertainty has been resolved so it represents the minimum possible basis achievable. Summary statistics for the ten-year period analyzed are shown in table 2.[9]

Table 2: Variance and Mean of Spot Price and Basis (\$/cwt), 2002 - 2011

Month	Spot	Ex-Post	3 basis	4 basis	90-day basis
σ^2	12.262	0.089	0.531	1.713	0.237
μ	14.576	0.060	0.380	0.926	0.229

As shown in table 2 cash market participants are trading price risk for basis risk as the basis is less variable than the spot price in all hedging scenarios analyzed. This is consistent with basis risk inherent in livestock (e.g. Purcell and Hudson, 1985). The ten year average ex-post basis, assuming perfect information, was only \$0.06 per cwt of milk. For the ten year period the ex-post basis ranged from a low of -\$0.78 per cwt in August 2003 to a high of \$1.11 in July 2007. The variance of \$0.09 demonstrates that it is possible to experience on average low basis risk when correctly identifying the mover. However, even with perfect foresight - or through luck - the standard deviation of \$0.30 indicates that there remains the potential for significant financial exposure to basis risk (such was the case in August 2003 or July 2007).

A pure-strategy approach of always using the class 3 contract to class 1 cross-hedge yields significantly poorer results when compared to the ex-post basis. A pure-strategy class 3 based hedging approach increased the ten-year average basis to \$0.38 per cwt, an increase of more than 533%. The class 3 basis ranged from as low as -\$0.78 per cwt on the August 2003 contract to a high of \$3.84 per cwt on the June 2011 contract. The variance of the sample was significantly higher at \$0.53 per cwt with a standard deviation of \$0.73 per cwt. The June 2011 basis of \$3.84 per cwt highlights the riskiness associated with using the wrong contract to underlie the class 1 mover when using a pure-strategy class 3 approach.

[9] The basis measurements assume that a contract holder will liquidate the contract prior to expiration on the date the class 1 price is announced.

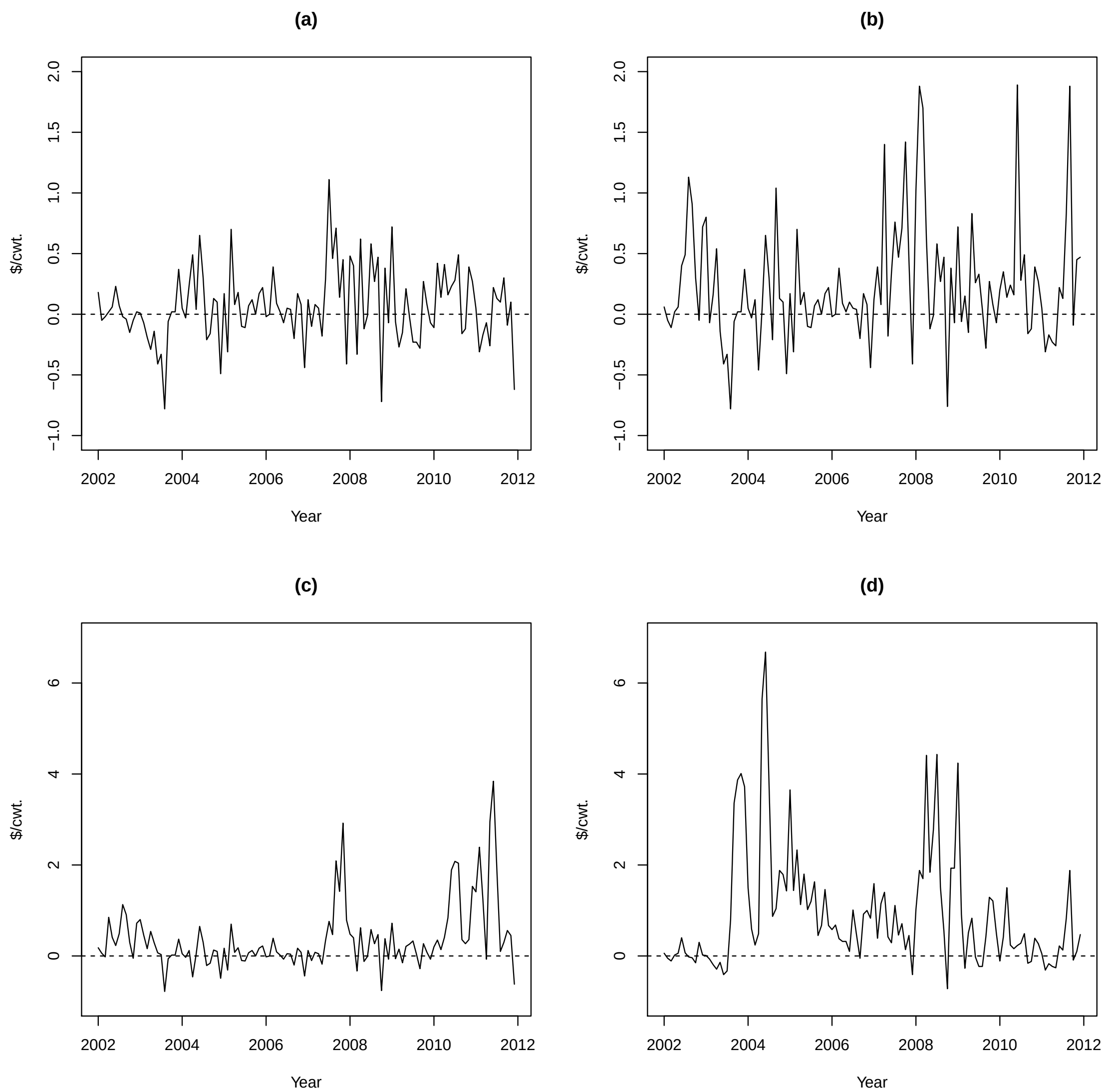

Figure 3: Closing Basis, 2002 - 2011. (a) Ex-post basis, (b) 90-day basis, (c) Class 3 basis, (d) Class 4 basis.

A pure-strategy class 4 based hedging plan increases the ten-year average basis to \$0.93 per cwt, 144% higher than the class 3 basis. The class 4 basis ranged from as high as \$6.68 per cwt on the June 2004 contact to a low of -\$0.72 per cwt on the October 2008 contract. The variance of the sample was significantly higher at \$1.71 per cwt with a standard deviation of \$1.31 per cwt. It is obvious that using a class 3 or 4 only approach to cross-hedge class 1 milk is inefficient at minimizing basis risk as it increases exposure to the mover effect. To minimize this exposure a trader could utilize a mix of both class 3 and class 4 contracts to cross-hedge class 1 milk. However, due to the switching nature of the price series it is difficult to identify which price will drive the class 1 mover at distant delivery dates. For this analysis a 90 day hedging strategy was used to identify the contract best suited to cross-hedge class 1 milk. 90 days prior to the announcement of the class 1 mover the highest valued futures contract between class 3 or class 4 was isolated as the contract most likely to drive the mover. This contract was used as the underlying asset on the class 1 cross-hedge. Employing this methodology did not eliminate exposure to the mover effect because it left open the potential for price movement during the 90-day window.

The basis improvement using the 90-day strategy resulted in a ten-year average basis of \$0.23 per cwt, representing a decrease of nearly 40% from the class 3 basis. Even though exposure to the mover effect was reduced, the 90-day approach was still 279% higher than the results from the ex-post analysis. During the 10-year period analyzed the 90-day basis ranged from as low as -\$0.78 per cwt on the August 2003 contact to as high as \$1.89 per cwt on the June 2010 contract. The variance of the sample was \$0.24 per cwt with a standard deviation of \$0.49 per cwt. Comparing the different hedging strategies (not including ex-post) the 90-day strategy of cross-hedging class 1 milk using the F^{max} contract resulted in the lowest basis mean and variance. A low basis mean and variance however are not the only measure of success. In order to provide risk management opportunities the futures contract must reduce exposure to variable cash prices.

4 Hedge Ratio and Effectiveness

Up to this point we have demonstrated that due to the different aspects of the underlying asset and the cross-hedged asset there exists a significant amount of financial risk attributable to basis. As a result it is not optimal for a class 1 milk buyer or seller to cross-hedge 100% of their cash exposure. Instead, in order to minimize the risk of cross-hedging the hedger should identify and use a hedge ratio (Myers and Thompson, 1989; Hull and Basu, 2010). The hedge ratio is the proportion of spot positions that should be covered by futures market positions and is generally equal to the covariance between the spot and futures prices divided by the variance of the futures price: (i.e. $\frac{Cov(S,F)}{Var(F)}$). The hedge ratio as defined by Hull and Basu provides a ratio of the unconditional moments, and is inappropriate according to Myers and Thompson. As a solution Myers and Thompson suggest a generalized hedge ratio to account for the presence of conditional information available at the time a hedging decision is made.

The generalized optimal hedge ratio for this analysis is obtained using an augmented reduced form model of the spot price with the change in the futures price (ΔF) as the augmenting variable and F^{max}_{t-j} as the relevant conditioning information.[10] This method imposes the restriction that milk futures markets are unbiased. The OLS estimator is given by: $S_t = \delta\Delta F^i_t + \psi F^{max}_{t-j} + \varepsilon_t$ for i = 3, 4, max, with the change in price measured over a period of time equal to the hedge interval (j). Hedging intervals of 30 and 90 days were used to compute the generalized optimal hedge ratios. The OLS estimate of δ represents the generalized optimal hedge ratio.

Table 3: Generalized Optimal Hedge Ratio

Model	$\hat{\delta}$	Std. Err	$\hat{\psi}$	Std. Err.	n
(1) $S_t = \delta\Delta F^3_t + \psi F^{max}_{t-30} + \varepsilon_t$	0.591*	0.062	1.004*	0.003	119
(2) $S_t = \delta\Delta F^3_t + \psi F^{max}_{t-90} + \varepsilon_t$	0.977*	0.053	0.999*	0.007	40
(3) $S_t = \delta\Delta F^4_t + \psi F^{max}_{t-30} + \varepsilon_t$	0.416*	0.079	1.010*	0.003	119
(4) $S_t = \delta\Delta F^4_t + \psi F^{max}_{t-90} + \varepsilon_t$	1.004*	0.148	1.013*	0.015	40
(5) $S_t = \delta\Delta F^{max}_t + \psi F^{max}_{t-30} + \varepsilon_t$	0.729*	0.061	1.010*	0.002	119
(6) $S_t = \delta\Delta F^{max}_t + \psi F^{max}_{t-90} + \varepsilon_t$	0.951*	0.044	1.020*	0.006	40

* p-value < 0.001

Results of the OLS analyses in table 3 indicate that as the hedging interval decreases changes in the class 3 and class 4 milk futures contracts, given by ΔF^i_t, have significantly less explanatory power for determining the cash price - lowering the optimal hedge ratio. Optimal hedge ratios for class 3, class 4, and F^{max} reduce by 40%, 59%, and 23% when the hedging interval is reduced to 30 days. This is consistent with Maynard et al. who found that longer hedging intervals were more effective at reducing cash price risk. Hedge ratios greater than one, as seen with class 4 futures, occur when the cash price changes more than the futures price. This type of hedge is referred to as a Texas hedge and implies that a market position greater than the size of the exposure should be taken - increasing the risk exposure to the trader.

Table 4: Class 1 Cross-Hedge Results using CME Milk Futures

Interval	Moment	No Hedge	Ex-Post	Class 3	Class 4	Max
(j=90)	μ	14.58	14.07	14.38	14.50	14.54
	σ^2	12.26	8.25	8.05	9.89	9.28
	Δ_{NH}		-32.8%	-34.3%	-19.4%	-24.4%
(j=30)	μ	14.58	14.12	14.44	14.56	14.58
	σ^2	12.26	10.19	10.83	11.49	11.60
	Δ_{NH}		-16.9%	-11.6%	-6.3%	-5.4%

In order to measure the hedge effectiveness of CME milk futures when cross-hedging class 1 milk, the averages and variances of the net milk price ($C^i_t = F^i_{t-j} + b^i_t$) were computed for each of the hedging strategies using a 30 and 90-day hedging interval (table 4). Over

[10] We investigated whether other lagged futures prices should be included as conditioning information in the OLS estimator and found that lagged class 3 and class 4 futures prices were statistically insignificant.

the 10-year period analyzed cross-hedging using CME milk futures reduced the average milk price and sample variance compared to not hedging at all. Additionally, we found that 90-day hedging intervals had lower sample means and variances than the 30-day interval for all hedging strategies. When comparing the various hedging strategies, the pure-strategy class 3 performed the best and was able to reduce the cash price variance by 34.3% (compared to no hedge) when a 90-day hedging interval was selected (represented by Δ_{NH}). At a hedging interval of 30-days the reduction in the cash price variance using a pure-strategy class 3 approach was 11.6%.

When comparing the average cash price absent hedging to the average net price under the various hedging strategies we see that cross-hedging can reduce the average class 1 milk price by as much as \$0.57 per cwt (assuming perfect foresight). A more realistic reduction is found with the class 3 hedging strategy where the average class 1 milk price decreased by \$0.20 per cwt using a 90-day hedging interval. The interesting point with the cash price reduction is that it puts an upper bound on the average transaction costs for cross-hedging. Transaction costs greater than \$0.20 per cwt may discourage cross-hedging endeavors because the costs of hedging could outweigh the benefits from a reduction in the cash price mean and variance.[11] Additionally, for hedging strategies that do not offer as significant a reduction in the average net milk price (i.e. class 4 and F^{max}) the limit on transaction costs is less forgiving on average - leaving \$0 - \$0.08 per cwt to cover transaction costs.

An important consideration when assessing the effectiveness of the cross-hedge is that the basis contributes significantly to the variance of the net milk price. For example the variance of the class 3 milk futures contract alone at a 90-day hedging interval was only \$6.52 per cwt, 47% lower than the variance in the class 1 cash price. When the basis associated with this hedge is added the variance increases by 23% to \$8.25 per cwt, significantly reducing the effectiveness of the cross-hedge. Calculations made for each of the hedging strategies over the different hedge intervals provide similar results. We conclude that due to basis risk the ability for milk futures contracts to reduce the cash price variance is limited.

5 Is Basis Predictable?

The cross-hedge effectiveness when using class 3 and class 4 futures indicated that the underlying forces of supply and demand respond in such a way that less than half of the cash price variance is eliminated by hedging when using a 30-day or 90-day hedging interval. If the remaining risk can be reduced to some predictable basis with some reliability then the futures market may provide direct risk management opportunities for cash market participants.

The first step to measure the predictability of the basis is to test whether the price series behaves as a stationary or non-stationary process. Stationarity is an important consideration because it indicates that the mean and variance parameters of the process do not depend on time. If the data is stationary then we will develop a forecast for the conditional expectation

[11] Transaction costs represent to costs associated with participating in the commodity exchange market and may include brokerage fees, search and information costs.

of the basis using an autoregressive model (AR). Before testing for stationarity the data was decomposed to remove the trend cycle and seasonal factors using a moving-average filter and seasonal residuals of the smoothed data.

Based on a Dickey-Fuller test for a unit root, we can reject the null hypothesis that class 3 and class 4 basis are non-stationary. As a result, to determine the candidate models appropriate for prediction the first 50 lags of the sample autocorrelation function (ACF) and partial autocorrelation functions (PACF) were examined for both the class 3 and class 4 basis. The ACF and PACF indicated an AR(1) for both class 3 basis and class 4 basis as the candidate models.

The first 110 observations of the class 3 and class 4 basis were used to estimate the parameters of the AR(1) models. The remaining 10 observations were used to assess the goodness of fit for the prediction models and measure the prediction errors. The AR(1) models are given by: $(1 - \phi_1^i \mathbf{B})Y_t^i = Z_t^i$, where $\mathbf{B}$ is the standard backshift operator and $\{Z_t^i\} \sim WN(0, \sigma_i^2)$ for $i = 3, 4$.

Table 5: Autoregressive Model Parameter Estimates

	Parameter	Std. Err	σ^2	Model
AR(1) Class 3	0.473	0.087	0.238	$(1 - 0.473B)Y_t^3 = Z_t^3$
AR(1) Class 4	0.598	0.075	0.983	$(1 - 0.598B)Y_t^4 = Z_t^4$

Based on the results of the estimated AR models the relationships in table 5 are suggested for the class 3 and class 4 basis. The results indicate that there exists a relationship between the current basis and lagged observations of the basis when using either class 3 or class 4 to form the cross-hedge. When plotting the residuals of the AR models we see that there remains a considerable amount of basis risk not explained by the linear prediction models (figure 4). Assessing the goodness of fit for the time series residuals in the models we see that the residuals are centered around zero. The residuals from the AR(1) for class 3 basis range from -\$1.12 to \$1.93 per cwt. The residuals from the AR(1) model for class 4 basis range from -\$1.52 to \$4.65 per cwt. Within each series we also observe periods where the basis appears more variable (2007-2008 and 2010-2011 for the class 3 AR(1) residuals, and 2003-2005 and 2008-2009 in the class 4 AR(1) residuals). It is possible that the distribution of the residuals may be close to normal, but have two different variances. We conclude that, except for the variance problem, the models fit reasonably well.

Using the AR parameters we forecast the basis for ten months. The ten months forecasted for the basis correspond to the ten observations not included in the model estimation. As demonstrated in figure 5 the predictive power of the AR models are very low. The mean predicted class 3 basis from the AR(1) model was \$0.12 per cwt compared to the mean observed basis of \$1.06 per cwt. The mean predicted class 4 basis from the AR(1) model was -\$0.04 per cwt compared to the mean observed basis of \$0.29 per cwt. The corresponding mean square prediction errors are \$2.40 and \$0.58 per cwt for the class 3 and class 4 prediction models respectively. These results suggest that the AR models, despite fitting the data

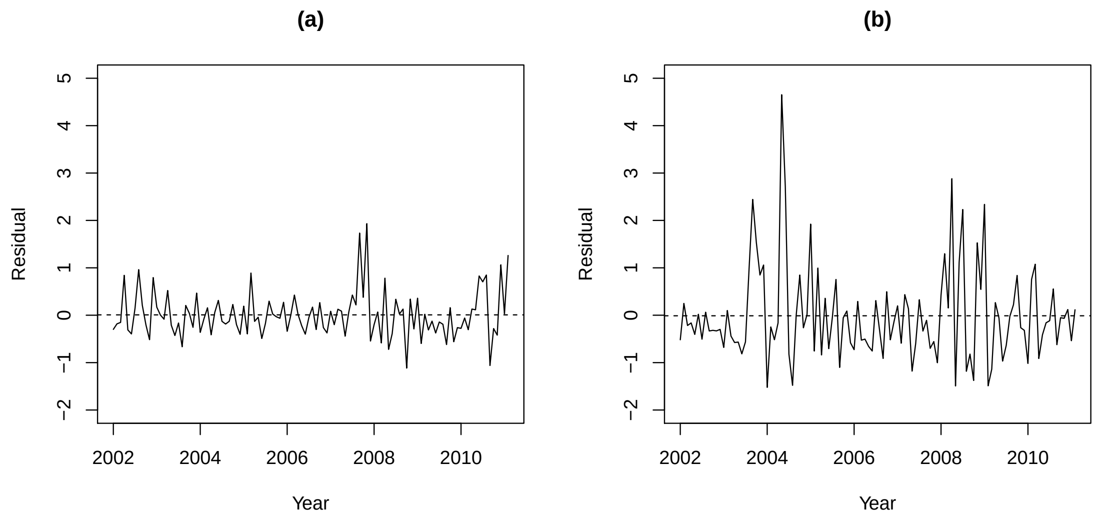

Figure 4: Autoregressive Model Residuals. (a) Residuals from AR(1) model on class 3 basis, (b) Residuals from AR(1) model on class 4 basis.

reasonably well, have little predictive power in forecasting basis.

The results included in section 4 and this section provide evidence that the class 3 and class 4 futures contracts are imperfect tools to cross-hedge class 1 price risk. At sufficient hedging intervals class 3 and class 4 contracts can reduce the cash price variance; however, the reduction is less than half. Milk futures contracts can still reduce the cash price variance at nearby hedging intervals but traders should use significantly smaller hedge ratios. Additionally, the poor performance of the AR models in forecasting the basis shows that the basis lacks convergence to some predictable level, resulting in a considerable amount of risk exposure for the trader. The effectiveness of cross-hedging as a means of transferring price risk is inversely related to the lack of predictability in the basis. Additionally, the unpredictable nature of the basis may result in lower utility for a risk averse agent.

6 Policy Implications

The results of this study could have implications in the policy and private market arena. From a policy standpoint, to reduce the basis attributable to Federal milk pricing provisions there are several possible solutions. Most notable, the USDA could alter the interpretations for minimum price adjustments to allow for voluntary forward contracting of class 1 milk. Class 1 milk under forward contract would be exempt from FMMO minimum pricing provisions providing fluid markets participants the ability to more directly manage their price risk. An additional benefit of forward contracting is the lack of margin calls when using a forward price contract. Fluid market participants would be able to lock-in a forward price without the need to establish hedge lines of credit. Second, producers and their cooperatives,

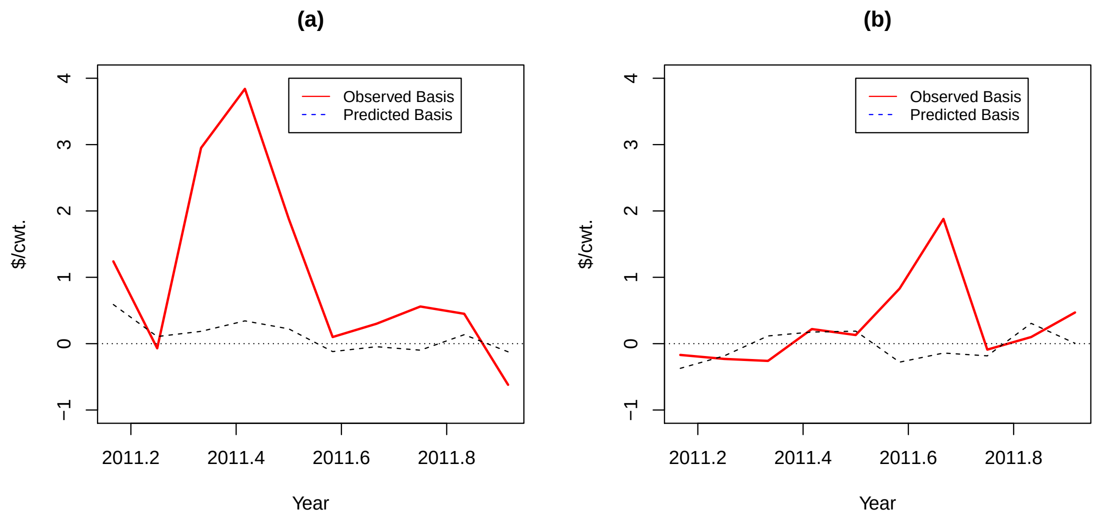

Figure 5: Basis Forecast. (a) Observed and predicted class 3 basis, (b) Observed and predicted class 4 basis.

through the USDA, could consider fixing the value of the higher-of component in milk pricing. Over the ten-year period analyzed the higher-of mechanism added $0.38 per cwt to the class 1 mover price (calculated by subtracting from the mean cash price the mean advanced class 3 pricing factor). Fixing the higher-of component in milk pricing removes the mover uncertainty in the class 1 milk price and would reduce basis exposure. Third, we propose the USDA consider alternative price discovery methods such as using CME settlement prices or lagged manufacturing pricing similar to the BFP as the price discovery method for class 1 milk. Prices based on CME settlement prices or one month lagged manufacturing prices would allow for the class 1 mover and the underlying CME contract to converge in price.

The introduction of a cash settled class 1 mover contract traded on the exchange would represent a private market solution. In discussions with industry sources we found that a class 1 mover contract is a common request to the CME. This product would completely eliminate both the advance and mover effects that are problematic when using class 3 or 4 futures. The class 1 mover contract can be designed to settle to the announced class 1 price (without location differentials) and its value can capture the price switching associated with the higher-of mechanism built into the class 1 mover. This contract would, by design, reduce basis risk and provide fluid milk market participants the ability to fully hedge the financial risk associated with fluid milk prices. Concerns over liquidity in milk futures markets; however, may be warranted as a class 1 mover contract would compete with class 3 and 4 contracts for speculative traders who act as market makers.

7 Conclusion

This study has examined the risk management opportunities for class 1 cash market participants through the use of CME milk futures contracts. The study considers a variety of futures price cross-hedging scenarios using class 3 and class 4 milk futures contracts. The results suggest that regardless of which hedging strategy is employed CME milk futures contracts cannot account for the advance and higher-of dynamics inherent in the FMMO class 1 milk price formula. The class 3 and class 4 futures contracts have inconsequential effects on reducing the cash price variance at nearby hedging intervals, and techniques to forecast the expected basis perform poorly compared to observed levels. These limitations to fluid milk hedging hinder risk reduction and revenue stability for both buyers and sellers of class 1 beverage milk.

In order to achieve the over-arching goal of promoting stability in prices and marketing relationships the USDA (at the behest of producer groups and their cooperatives) eliminated BFP pricing in favor of advanced pricing that incorporated the highest valued manufacturing class of milk into the class 1 value. By changing the minimum pricing formulas the ability for producers and processors to shift or manage the price variability for approximately 55 billion pounds of milk produced and sold in beverage form in the US each year was sacrificed.

The U.S. dairy sector will continue to see an increased focus on price discovery, risk management and price variability leading up to the USDA Farm Bill. Programs designed to facilitate risk management, such as the Dairy Security Act proposed by Rep. Collin Peterson (D-MN), are popular solutions to help reduce government spending in the agricultural sector. Considering the popularity of risk management, it is counterintuitive that the Federal government would have milk pricing provisions that complicate milk hedging strategies in only the beverage milk sector. While none of the proposed solutions consider the welfare tradeoffs associated with basis and agent utility, the initiatives do provide immediate solutions to volatile milk prices and help to facilitate additional risk management on behalf of milk producers, processors and end-users.

The proposed solutions do not jeopardize the integrity of the FMMO program. In fact, voluntary programs such as forward contracting or new price discovery methods would provide avenues for producer and processor profitability while ensuring an adequate supply of pure and wholesome milk for the consumer. Market services currently provided by the FMMO program, such as statistics, auditing, and testing are indispensable, and will continue to be valuable tools for accommodating risk management strategies. The popularity of risk management as a solution suggests that USDA be involved in recognizing and designing cost-effective programs for managing risk in the modern dairy economy. Failure to plan accordingly could result in dairy policies that are outdated in their scope, costly to the industry, and ultimately discarded.

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