Quantifying Impacts of Class I Milk Price Formula Reform: A Study of FMMO Uniform Milk Price Volatility and Class I Milk Hedging

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Jordan Clark

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Dr. Marin Bozic, Advisor

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ABSTRACT

Up until the enactment of the 2018 Farm Bill ("Agricultural Improvement Act of 2018"), available CME futures contracts did not consistently converge to costs paid by manufacturers of packaged milk. Due to the lack of convergence, CME dairy futures were inadequate risk management tools for the packaged milk industry.

Seeking to increase convergence between the available CME futures contracts and underlying costs in the packaged milk industry, dairy trade organizations proposed a reformed pricing formula in 2017, which was ultimately included in the 2018 Farm Bill and enacted beginning with the May 2019 Class I milk price.

The newly reformed formula was designed to strengthen the price relationship between available CME futures contracts and Advanced Class I skim milk prices without having a long-term directional influence on average Advanced Class I skim milk prices paid by packaged milk manufacturers or milk producer pay prices.

This study quantifies the impact that the newly reformed pricing formula would have had on milk producer pay prices between 2000 and 2017 – the period that informed the design of the new pricing formula. This is the first study to quantify how the change of the pricing formula would have affected producer pay prices in different regions and the first to identify optimal hedging ratios of the reformed pricing formula.

We find that between January 2000 to December 2017, average uniform prices for each federal milk marketing order would have differed by less than $0.01/cwt when comparing the previous and current Class I pricing formulas. We also find that that uniform prices are more volatile in federal milk marketing orders with the highest Class I utilizations and, had the newly reformed pricing formula been in place, would have reduced volatility in all FMMOs between 2000 and 2017.

We also find that the basis risk of varying hedging strategies is significantly reduced under the reformed formula as compared to the previous formula. Furthermore, we identify optimal hedge ratios for the reformed Class I formulas.

Key Words: Milk price, Fluid milk hedging, Market volatility, Dairy policy, Classified pricing, Federal Milk Marketing Order, Basis risk

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Introduction

In 2017, dairy farms produced over 212 billion pounds of milk in the United States, of which 64% were regulated by 10 geographically distinct Federal Milk Marketing Orders (FMMOs) spanning much of the country (USDA AMS, 2017). A single order is referred to as an FMMO. FMMOs designate four classes of milk utilization and pricing formulas for each of those classes. The price for beverage milk ("Class I"), is designed to be consistently higher than the prices of milk manufactured into non-beverage products (Bailey, K., and P. Tozer. 2001). Class I accounted for 40 billion pounds of milk in 2017. Milk producers are paid based on the pooled value of milk, rather than the utilization of their own shipped milk. Within a pool, milk utilization varies across each of the 10 orders. Higher Class I utilization within a milk pool consistently leads to higher prices paid to dairy producers in an FMMO.

Since the reform of Federal Milk Marketing Orders in 2000, futures contracts have existed for manufacturing milk uses and were available to be used by the industry to cross-hedge exposure to Class I milk prices. However, for Class I milk price exposures, available hedging instruments have been shown to have significant basis that at times exceeded price variation (Newton and Thraen, 2013). The lack of effective risk management tools available to the packaged milk industry discouraged flat-price agreements with retail and foodservice milk buyers who wished to set budgets to known costs, a necessity for managing and forecasting firm profits.

The choice between high price risk or high basis risk – and not knowing which would be greater – may have also played a role to discourage innovation in a category already in long-term decline as retail and food service establishments increasingly offer milk alternatives such as nut- and soy-derived imitation fluid milk beverages with more predictable margins.

In October 2017, the International Dairy Foods Association, a trade association for dairy manufacturers, and the National Milk Producers Federation, a trade organization for dairy cooperatives, jointly proposed a change to the Class I skim milk pricing formula which eliminated the major source of basis risk when cross-hedging with Class III and Class IV milk futures. The change was designed to have no long-term directional bias on milk prices.

The Agriculture Improvement Act of 2018 (Farm Bill) was enacted on 20 December 2018 and changed the pricing formula for advanced skim milk in Federal Milk Marketing Orders. Prior to this legislation, the advanced skim milk price was calculated as the higher of the monthly advanced pricing factors for Class III and Class IV skim milk, plus a region-dependent Class I differential.

Under the newly reformed pricing formula, the Class I skim milk pricing formula became the simple average of the monthly advanced pricing factors for Class III and Class IV skim milk, plus \$0.74 per cwt, plus the applicable Class I differential. The first Class I milk price calculated under the new formula was the May 2019 advanced milk price which was announced on 17 April 2019.

Prior work has been done to measure basis risk when hedging Class I milk with existing milk futures contracts under the previous formula (Zylstra and Uryasey, 2004). We find that the newly reformed skim milk pricing formula has compelling positive consequences for risk management. Previous to this paper, no work has been done to measure how producer pay prices would be affected across different Federal Milk Marketing Orders had the reformed formula been in place.

This study has two objectives. The first is to quantify impacts to producer uniform prices in all 10 FMMOs when they are calculated with the proposed formula changes. The second objective is to measure basis risk, optimal hedging ratios, and the change in conditional variance of the hedging basis on the Class I price exposures using Class III and Class IV futures under the previous and reformed Class I pricing formulas. Historical data comes from FMMO pricing publications and the CME.

We hypothesized Class I utilization is positively correlated with variance of uniform prices. We also expected to see a decline in the volatility of uniform prices when uniform prices were calculated with the newly reformed Class I formula. Under the reformed formula, basis risk was expected to decline significantly, but not entirely, due to remaining temporal affects associated with the announcement of Advanced Class I milk prices and the later-dated expiration of futures contracts that settle to Announced prices.

Federal Milk Marketing Orders

Federal Milk Marketing Orders, established over 80 years ago, set the minimum prices regulated milk processors pay for milk in the USA. The system was designed to assure consumers an adequate supply of wholesome milk at a reasonable price; to promote greater producer price stability and orderly marketing and provide adequate producer prices to ensure an adequate current and future Grade A milk supply.

FMMOs achieve these objectives by mandating beverage milk processors in a regulated order participate in a pool. The orders set the minimum prices paid for raw milk manufactured into packaged fluid milk at higher levels than milk prices for other manufactured uses. This introduces revenue into the pool which incentivizes manufacturers (called "supply plants") of more storable dairy products to participate in the pool. Additionally, by enforcing minimum performance standards for pooled supply plants, the orders ensure packaged milk plants have a reliable supply of raw milk.

Each FMMO encompasses a specific geographic region (marketing area) in which Class I processors compete with each other for sales of beverage milk to outlets such as retail grocers, convenient stores, and restaurants. Each FMMO is distinguished by a number and a description of the region. Since instituted in 1937, regulation has led to fewer, larger FMMOs. In 2017, there were 10 FMMOs. (Figure 1). An eleventh FMMO was established in 2018 in California, replacing a state-run order with slightly different pricing regulations. The California FMMO is not included in this analysis.

Utilization of milk varies by FMMO. In Florida, Southeast, and Appalachian FMMOs, which are near east coast population centers, Class I utilization is highest. The hot and humid climate in those areas is comparably less suited for milk production than drier or cooler FMMOs with lower production costs and concentrated manufacturing clusters for storable, "hard" dairy products. For example, FMMO 30, which includes Wisconsin and Minnesota and is well known for its cheese production, has the highest Class III milk utilization and the lowest Class I utilization of all 10 FMMOs (Table 1).

Table 1. Milk Utilization by Federal Milk Marketing Order (2017)

Federal Milk Marketing Order	Class I	Class II	Class III	Class IV
1 - Northeast	32%	24%	26%	18%
5 - Appalachian	60%	16%	5%	10%
6 - Florida	84%	11%	2%	3%
7 - Southeast	69%	14%	9%	8%
30 – Upper Midwest	10%	5%	81%	4%
32 - Central	31%	11%	41%	17%
33 - Mideast	31%	19%	32%	18%
124 – Pacific Northwest	24%	7%	34%	35%
126 - Southwest	32%	11%	40%	17%
131 - Arizona	26%	9%	24%	41%

Classified Milk Pricing

The USDA publishes two milk price reports each month. The “Announcement of Advanced Prices and Pricing Factors” establishes the prices of components that make up Class I milk prices and Class II skim milk prices for the following month. It is published no later than the 23rd of each month and is calculated from prices and volumes reported for the most recent two-week period in the National Dairy Products Sales Report. The “Announcement of Class and Component Prices” is a report that establishes the minimum prices for the components of the other two classes of milk: Class III, and Class IV; and the price of Class II butterfat. It is published near the end of each month and is calculated using the most recent four or five weeks of data in the National Dairy Products Sales Report and sets prices for that month.

These two price reports establish the minimum pay price for milk components –protein, nonfat solids, other solids, skim milk and fat that regulated Class I plants and pooled supply plants pay. FMMO regulated milk has four classifications, though the milk is compositionally undifferentiated:

1) Class I – milk manufactured into beverage milk products.
2) Class II – milk manufactured into soft manufactured dairy products such as ice cream, yogurt, sour cream and cottage cheese.
3) Class III – milk manufactured into cheese and whey products.
4) Class IV – milk manufactured into butter, nonfat dry milk, and ingredients used for secondary processing.

Each class of milk has distinct pricing formulas, and each formula contains, as variables, the market price of one or more of the four recognized commodity dairy products: butter, nonfat dry milk, Cheddar cheese and dry whey.

The Agricultural Marketing Service (AMS) branch of the USDA surveys the industry each week and publishes national wholesale prices and volumes for butter, nonfat dry milk, cheddar cheese, and dry whey in a report named the National Dairy Products Sales Report. These prices and volumes are used to calculated weighted average prices which are variables in the monthly milk price formulas.

Milk Pooling

The milk pool is the total value of all milk regulated by an FMMO. It includes all the milk processed by regulated Class I plants in the order, called pool distributing plants, and the milk processed by manufacturing milk plants that have chosen to, and are approved to, participate fully or partially in the pool, called pool supply plants. Table 2 categorizes the FMMO nomenclature of dairy processing plants as manufacturing milk or beverage milk.

Table 2. Guide for Understanding Federal Milk Marketing Order Terminology

Dairy Plant Type	Products	Pool Participation
Class I Beverage Fluid Milk	Packaged Beverage Milk	Always Pool Distribution Plants
Class II Manufacturing Milk	“Dairy Softs” e.g. Ice Cream and Yogurt	Option Pool Supply Plants
Class III Manufacturing Milk	Cheeses and Whey	Option Pool Supply Plants
Class IV Manufacturing Milk	Butter and Milk Powders	Option Pool Supply Plants

The Class I milk price formula was designed to consistently be the highest priced use of milk to incentivize supply plants to join the pool and become qualified. By doing so, these supply plants are able to pay milk producers a higher milk price than what would otherwise be possible from the economics of their operations.

With few exceptions, all beverage milk plants must participate in FMMO milk pools, but manufacturing milk plants (Class II, III, and IV) opt into pool by their own choice and do so to draw revenue out of the pool.

To participate in the pool, manufacturing milk processors must become qualified pool supply plants which means the manufacturer meets a performance standard of supplying milk to Class I plants, as dictated by the rules which are established in each FMMO.

The value per unit of pooled components is almost always higher than the component-based obligations for Class II, III and IV supply plants which incentivizes supply plants to participate in the pool.

FMMOs regulate the prices paid by fluid milk manufacturing plants based on plant location and based on the markets where packaged milk is sold. When a Class I plant in an unregulated area sells packaged milk into a FMMO, it must pay minimum FMMO prices and the appropriate Class I differential on those sales based on its location. Other dairy product distribution however is not tracked. For example, cheese plants located in FMMO

30 ship to markets all over the USA and beyond without having to report the distribution of those products to any FMMO office.

Because Class I prices are announced approximately six weeks in advance of the other Class prices, swift changes in commodity prices can cause Class I prices to be lower than one of more of the other classified milk prices as determined by the pricing formulas (Zylstra and Uryasey, 2004). During these times, a pool supply plant may end up paying into the pool instead of drawing from it. Such scenarios create an incentive for supply plants to de-pool some or all their milk.

De-pooling has a set of consequences to both producers and potential pool supply plants. To discourage de-pooling, some FMMOs only allow pool supply plants to pool a percentage of the milk that they pooled during the preceding month. For FMMO 33, that number is 115% for all months except March when it is 120%. If a pool supply plant pooled 10 million pounds of milk in March but decided to pool just 2 million pounds in April, then the most it could pool in May would be 2.3 million pounds and it would take 13 months to get back to the March level of pool participation. These rules are in place to reduce pool supply volatility. In FMMO 33, the Class I price was lower than all of the other Class prices in just 12 of the 216 months between January 2000 and December 2017.

To preserve the integrity of the pool, FMMOs also prohibit forward price agreements between dairy producers and Class I milk shipments. Were it not for this regulation, there would be times when a pool would be shorted funds because the forward contracted prices were below the announced Class I prices.

Class I Risk Management

There are six dairy futures contracts traded on the Chicago Mercantile Exchange. They are announced butter, announced cheese, announced nonfat dry milk, announced dry whey, announced Class III milk and announced Class IV milk. Each of these contracts settles to USDA published prices in the monthly Announcement of Class and Component Price report. For simplicity, we will focus on the use of Class III and IV futures contracts as a cross-hedge for Class I milk.

We define “basis” as the difference between the announced price of Class I milk and the settlement price of the hedging instrument (Classes III and IV futures) at the time of contract expiration (i.e. when USDA releases the Announced Prices and Pricing Factors report). Newton and Thraen (2013) explained that accepting Class I basis could be viable if it converged to a predictable level, but that this was a challenge when hedging the previous Class I formula.

The previous Class I mover (figure 2), which was the maximum of Advanced Class III Skim Milk Prices and Advanced Class IV Skim Milk prices, did not always correlate well to a single hedging instrument –Class III or Class IV futures.

Newton and Thraen (2013) demonstrated two kinds of basis associated with hedging the previous formula for Class I milk: 1) the index effect, caused by incorrectly forecasting which Class price would drive the formula, and 2) the temporal effect, caused by differences in two-week Advanced Prices and Announced Prices that futures contracts settle to which include those same two weeks used to determine Advanced Prices plus two or three additional weeks of weighted average prices.

Between 2002-2011, the index effect averaged $0.367 per cwt, and the temporal effect averaged $0.013 per cwt when using Class III contracts prior to the 2018 reform. When hedging with Class IV contracts, the index effect averaged $1.008 per cwt and the temporal effect averaged -$0.082. Newton and Thraen (2013) found that several techniques to forecast expected basis performed poorly, though GARCH models used for forecasting Class III basis had some reasonable predicting power. This literature recommended "fixing or eliminating the higher-of component" of Class I milk pricing; and in October 2017, two major trade organizations representing both dairy cooperatives and dairy processor interests recommended doing so in a proposal that was ultimately included in the 2018 Farm Bill.

Newly Reformed Class I Skim Milk Price

The newly reformed Base Class I Skim Milk Price is the average of the average of advanced Class III and IV skim milk prices plus $0.74 cents per hundredweight. This change eliminates index basis when hedging 3.5% fat Base Class I milk with equal volumes of Class III and IV futures contracts.

Historically, averaging the Class III and IV advanced skim milk prices would have resulted in a lower price than calculating the maximum of Advanced Class III and Advances Class IV skim milk prices. The average difference between maximizing Advanced Class III skim milk prices and Advanced Class IV skim milk prices and averaging Advanced Class III and Class IV skim milk prices was $0.74 between 2000 and August 2017. To compensate milk producers for this discrepancy, the newly reformed Class I formula includes a constant $0.74 addition. The reformed base Class I formula for 3.5% fat milk is as follows:

(((advanced Class III skim milk and IV skim milk pricing factors) /2 + \$0.74)) X 0.965)

+ (Advance butterfat pricing factor X 3.5)

Materials and Methods

All 10 FMMOs publish monthly minimum pay prices obligated to regulated processors for each class of milk, as well as the complex breakdown of components used to compute all receipts of regulated milk into the blended prices producers are paid within each marketing area. Few FMMOs share the same reporting style and nomenclature, or even publish all the values needed to make the full computation of producer pay prices. We created a database and a unified nomenclature for all the data published by each separate FMMO from January 2000 through December 2017 and calculated variables that were not included in producer price reports with ancillary FMMO and USDA published data. This database fed into a uniform price calculator that generated scenarios for each FMMO.

Historical differences between the previous and newly reformed Class I skim milk pricing formulas were the greatest when Class III and IV advance skim milk prices diverged. To better understand this divergence, we looked for seasonal trends using basic measures of central tendency such as the mean and standard deviation of the advance Class III and IV skim milk spread for each month over the 18-year period.

We then measured the seasonal trend in milk components sold by producers to compare if the spread between skim milk values tended to be larger during seasons of lower milk component supply.

We calculated the standard deviation, maximum, and minimum prices for the monthly uniform milk price in each FMMO incorporating the newly reformed Class I Skim Milk Price and compared them to the same measures under the previous formula. We then plotted them against Class I utilization for each FMMO.

To align the market prices of USDA advanced prices with futures, we subtracted USDA monthly Class III prices from the following month's Class I prices, and did the same with Class IV prices. We calculated basis, standard deviation and average values of basis under the newly reformed pricing formula.

Results and Discussion

Impacts of the Newly Reformed Class I Skim Milk Price on Pay Prices

We found that the newly reformed Class I Skim Milk pricing formula would have resulted in an average difference of less than $0.01/cwt in uniform prices for each of the 10 FMMOs over the entire 18-year scenario, as was intended.

In 60% of months between 2000 and 2017, the newly reformed pricing formula would have calculated a higher uniform price than the previous formula. However, in periods of historically high volatility, the reformed formula had a tendency to calculate a lower price. For example, between January 2015 and September 2015, Advanced Class IV skim milk prices decreased by 48% and Advanced Class III skim milk prices decreased by just 20%. The previous formula, which maximizes the two prices calculated Class I prices that were $0.49/cwt higher on average than the newly revised formula, which averages the Advanced Class III and Advanced Class IV Skim Milk prices, There are seasonal patterns in the differences between the Class I Skim Milk prices calculated under the previous formula and the newly reformed pricing formula (Figure 5). In the pricing history, there were two outlying years, 2004 and 2008, that broke from the seasonality strongly enough to obscure the pattern when looking at all years (Figure 5).

When omitting 2004 and 2008, May, June, and July's average difference drop by $0.14, $0.21, $0.19 respectively (Figure 5). The trend for the remaining 16 years shows that when milk production is at its highest nationally in May, the newly reformed Class I Skim Milk price would have typically calculated a higher price than the previous Class I Skim Milk formula. And were it not for the abnormal spreads in 2004 and 2008, the $0.74 adjuster in the newly reformed Class I Skim Milk Formula would have been calculated at $0.68, $0.06 lower.

The median difference between the reformed skim milk price and the previous Class I formula between 2000 and 2017 was positive for each month with the median difference calculating to be $0.24 in March, and $0.30 in April and $0.16 in June – all months associated with seasonally higher milk production.

While the average price per cwt between the reformed and previous formula would have been approximately the same between 2000-2017, the Class I skim milk contributions to the pool would have been higher with the reformed formula because of seasonality. On a total dollar basis, all federal orders would have had higher modestly pool revenues had the newly reformed pricing regime been in place totaling $60 million between 2000 to 2017. The Northeast and Mideast Federal Orders would have experienced the greatest increase in revenues.

This raises two important questions:

1) Is a flat seasonal adjuster appropriate when there is a recognizable seasonal pattern in the difference between the previous and reformed formulas, especially during months of peak Class I skim milk production? (Table 3) (Table 4) (Figure 5) (Figure 12) (Figure 13)
2) Is it reasonable to anticipate such uncommon III-IV spreads, as was seen in 2004 and 2008, that producers should be compensated an extra $0.06 every month, and if they do occur, will the adjuster seem high enough (the adjuster would have been too low by $0.56 in 2008)?

Table 3. Frequency of Years the Reformed Class I Skim Milk Pricing Formula Would Have Calculated a Price Above or Below the Previous Formula

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
# of years Below	9	5	6	5	7	9	9	6	9	6	6	9
# of years Above	9	13	12	13	11	9	9	11	9	12	12	9
% of years Below	50%	28%	33%	28%	39%	50%	50%	33%	50%	33%	33%	50%

Table 4. Difference Between Previous Skim Milk Pricing Formula and Reformed

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2004	0.02	-0.43	-0.60	-0.58	1.99	2.65	1.57	-0.15	0.03	0.31	-0.06	0.14	0.41
2008	0.07	0.14	0.26	1.57	0.36	0.75	1.81	0.27	-0.20	-0.72	0.99	0.92	0.52
Full Data Average	0.15	-0.17	-0.19	-0.16	0.07	0.09	0.14	-0.09	-0.02	-0.10	0.07	0.18	0.00
04 &'08 Omitted	0.16	-0.17	-0.19	-0.24	-0.07	-0.12	-0.05	-0.11	-0.02	-0.09	0.02	0.14	-0.06
Median	-0.01	-0.33	-0.23	-0.29	-0.16	-0.07	-0.02	-0.15	-0.04	-0.13	-0.07	-0.02	

Impact on Volatility of Uniform Prices

The newly reformed Class I Skim Milk formula would have reduced Class I price volatility had it been in place over the 18-year period. The standard deviation from Class I skim milk prices would have decreased by about $0.13 from $3.07 to $2.93. This added stability has varying impacts on FMMOs because each has a different Class I utilization.

As expected, FMMOs with the highest Class I utilization experienced the greatest decrease in volatility of uniform prices. (Table 5) (Figure 7) (Figure 8) A 10% increase in Class I utilization leads to a $0.01 decrease in standard deviation had the newly reformed Class I Skim Milk Price formula been in place.

Table 5. Uniform Price Standard Deviation in each FMMO

FMMO	Class I Utilization	Standard Deviation		
		Previous	Reformed	Change
Florida	85%	3.881	3.792	-0.089
Appalachian	68%	3.613	3.543	-0.070
Southeast	66%	3.670	3.600	-0.070
Southwest	42%	3.452	3.421	-0.031
Northeast	41%	3.382	3.342	-0.040
Mideast	39%	3.366	3.333	-0.033
Central	33%	3.465	3.476	0.011
Arizona	32%	3.500	3.471	-0.029
Pacific Northwest	30%	3.444	3.422	-0.022
Upper Midwest	17%	3.461	3.445	-0.015

Class III skim and Class IV skim milk prices tend to move together and had a correlation of 82% between 2000 to 2017. During periods when advanced Class III and Class IV skim prices diverged, the previous Class I pricing formula would have usually calculated a higher price. For example, advanced Class IV skim milk prices decreased from $14.91/cwt in January 2008 to $6.18/cwt in December 2008. During that timeframe, Class III advanced skim milk prices fell from $16.53 to $7.04/cwt. The previous formula, which was the maximum of the two values, calculated an average skim milk price that was $0.52 higher than the reformed formula would have calculated.

In opposite fashion, between June 2009 and May 2010, advanced Class III skim milk prices climbed from $5.66/cwt to $8.19/cwt while advanced Class IV skim milk prices increased at about the same rate rising from $5.91/cwt to $7.82/cwt (+32%). In that timeframe, the newly reformed formula would have calculated prices that were on average $0.45/cwt higher than the previous formula.

Incentives to De-pool

Incentives to de-pool exist when a supply plant has to contribute money to, instead of drawing money from, the pool. We model these incentives for a supply plant whose obligation to the pool is for milk that has the same level of components as the total pool. As such, we counted the frequency of times that each FMMO's Class I price was lower than the respective uniform price.

We used the average location differential value in each FMMO to estimate an average Class I price for each FMMO. We then repeated the exercise using the reformed formula to calculate an estimated reformed uniform price. We found that it was relatively rare for the Class I price to be below the uniform price, and, had the newly reformed formula been in place, it would have had a minimal impact on de-pooling. (See Table 6)

Table 6. Frequency that Uniform Price exceeded Class I Price, 2000-2017

	Old Class I Price	Reformed Class I Price
Northeast	2	0
Appalachian	4	3
Southeast	6	8
Florida	0	0
Upper Midwest	3	4
Central	1	1
Mideast	3	2
Pacific Northwest	4	3
Southwest	1	1
Arizona	3	2
All Market orders	27	24

Effects on Hedging Basis

When cross-hedging Class I milk priced under the previous formula with Class IV futures for the full 18-year period, average basis was $0.93 and the standard deviation of the basis was $1.68. Basis was positive 70% of time. Cross-hedging with Class III futures resulted in a lower average basis of $0.47 and a standard deviation of $1.42. Class III basis was also biased to the positive, with basis being greater than zero 63% of the time.

Most often, positive basis resulted from the index effect of the higher-of Class III and IV skim milk component of the Class I formula. The index effect was never negative and is seldom offset by negative temporal effects. Temporal effects on basis converge to approximately $0.00 over time and are positive when announced prices exceed advanced prices, and negative under opposite market conditions.

Positive basis hurts Class I milk buyers, such as bottling plants and food service establishments, that hedge costs by buying futures because their milk costs usually settled at higher (sometimes much higher) prices than futures settlements. In contrast, sellers, such as milk producers, regularly gained from the basis. Whenever chosen futures instruments turned out to be the lower of the advanced Class III and IV milk values, the change in their cash price per hundredweight was greater than the change in the futures contract per hundredweight.

When the newly reformed Class I formula is applied, the index effect from basis is eliminated. Only the temporal effect remains and basis averages $0.01, with a standard deviation of $0.24; the distribution of basis is nearly even around zero. (see table 7)

Table 7. Basis Descriptive Statistics, 2000-2017

Parameter	Previous Formula		Reformed Formula
	Class III Futures	Class IV Futures	50/50 III-IV Futures
μ	0.50	0.95	0.01
σ	0.84	1.28	0.24
Max	4.62	6.63	1.05
Min	-0.85	-0.87	-0.82
% Positive	74%	80%	50%
% Negative	26%	20%	50%

Risk managers may manage basis by hedging only a portion of their price exposure with futures contracts. The volume covered by futures is known as a hedge ratio. Class I buyers may have interest in trusting a consistent hedge ratio if basis risk is known and stable. Formally this hedge ratio can be expressed as:

$$\delta = h_{t-j}/c_{t-j}$$

where h_{t-j} is the size of the futures position and c_{t-j} is the size of the cash position. The smaller the basis risk, the closer δ is to 1. Myers and Thompson (1989) suggest estimating a generalized optimal hedge ratio to determine δ and account for any conditional information available at the time a hedging decision is made. Consistent with Newton and Thraen (2013), we use the maximum of Class III and IV futures price $\left(f_{t-j}^{max}\right)$ as the relevant conditional information available to hedgers.

We created six linear regression models to estimate and compare variance conditioned upon the value of futures. Where Newton and Thraen focused on finding a model that reduced basis risk and allowing for hedging ratios that more closely converged to $\delta = 1$ with data from 2002-2011, we looked for a model that minimizes the variance of the regression errors, ε, with data from 2000-2017, and apply, for the first time, two models that incorporate the newly reformed Class I prices: one with hedging and the other without. Reduced conditional variance should coincide with reduced basis risk and hedge ratios closer to 1. We ran each model with hedging intervals of 30 days and again with 90 days.

Our approach is motivated by common fixed-pricing procurement practices that involve referencing the futures market for the expected cash price of the commodity, and then negotiating supplier contracts based on that reference. Price risk is inherent when suppliers have variable market costs and fixed sale prices, or when merchandizers have fixed costs and fluctuating sale prices.

The first model provides the conditional variance when Class I sales are priced by referencing the maximum of Class III and IV futures contracts, but no hedge position is taken:

$$class\ I = \alpha + \beta_1 * {f_{t-j}}^{(max)} + \varepsilon_t$$

Where Class I is the fixed cost of beverage milk when referencing the higher of milk futures. The second model simulates efforts to hedge the simulated fixed cash price unconditionally with Class III futures,

$$class\ I_t = \alpha + \beta_1 * f_{t-j}{}^{(max)} + \beta_2 * \Delta f_t^{(III)} + \varepsilon_t$$

where the second term estimates the ceteris paribus variation in Class I prices given the change in Class III futures price during period $t - j$, and β_2 becomes the estimated optimal hedging ratio when Class III futures are unconditionally used to hedge.

The third model instead uses Class IV futures:

$$class\ I_t = \alpha + \beta_1 * f_{t-j}{}^{(max)} + \beta_2 * \Delta f_t^{(IV)} + \varepsilon_t$$

Where the change in the futures price between the terminal hedging date and the time of the hedging decision is expressed as $\Delta f_t = f_t - f_{t-j}$

The fourth model hedges with the higher of Class III and IV deferred futures, aligning with the criteria for establishing the fixed price 30 or 90 days prior to the terminal hedge date:

$$class\ I_t = \alpha + \beta_1 * f_{t-j}{}^{(max)} + \beta_2 * \Delta f_t^{(max)} + \varepsilon_t$$

The fifth model is unhedged like the first model, but references both Class III and IV futures, and rather than assigning historical Class I prices as the dependent variable, we calculated Class I using the newly reformed formula $\left(class\ I^{(reformed)}\right)$ that incorporates the average of Class III and IV advance skim milk prices. Estimating the proper cash price for Class I in this scenario no longer requires guessing which of Class III and IV will settle higher, but taking both deferred contract prices as independent variables:

$$class\ I^{reformed} = \alpha + \beta_1 * f_{t-j}{}^{(III)} + \beta_2 * f_{t-j}{}^{(IV)} + \varepsilon_t$$

The sixth model simulates a scenario variant of last model where $class\ I^{(reformed)}$ is hedged with both futures contracts and optimal hedging ratios are given with the β_3 and β_4 estimators:

$$class\ I^{(reformed)} = \alpha + \beta_1 * f_{t-j}{}^{(III)} + \beta_2 * f_{t-j}{}^{(IV)} + \beta_3 * \Delta f_t^{(III)} + \beta_4 * \Delta f_t^{(IV)} + \varepsilon_t$$

We compared the conditional variance from the first model to each subsequent model and found significant reductions. With old Class I prices the risk of the index effect on basis decays with shorter time horizons, and the majority of basis risk is the temporal effect which cannot be mitigated with better forecasting of the Class I skim milk mover. The most significant reductions in conditional variance were measured using the sixth model, which incorporates the newly reformed Class I pricing. Table 8 and 9 lists the conditional variance for each model, along with the estimators.

Table 8. Class I Risk Management Evaluations Using Generalized Hedge Ratios for 90-day Hedge Intervals

90-day Models	$\sigma^2\|(x)$	$\Delta\sigma^2\|(x)$	β_1	β_2	β_3	β_4
$class\ I = \alpha + \beta_1 * f_{t-j}{}^{(max)} + \varepsilon_t$	2.45		1.06* (0.035)			
$class\ I = \alpha + \beta_1 * f_{t-j}{}^{(max)} + \beta_2 * \Delta f_t^{(III)} + \varepsilon_t$	0.49	-80%	0.97* (0.016)	0.79* (0.028)		
$class\ I = \alpha + \beta_1 * f_{t-j}{}^{(max)} + \beta_2 * \Delta f_t^{(IV)} + \varepsilon_t$	1.24	49%	1.04* (0.025)	0.70* (0.050)		
$class\ I = \alpha + \beta_1 * f_{t-j}{}^{(max)} + \beta_2 * \Delta f_{t-j}^{(max)} + \varepsilon_t$	0.37	85%	1.04* (0.014)	0.88* (0.026)		
$class\ I^{(reformed)} = \alpha + \beta_1 * f_{t-j}{}^{(III)} + \beta_2 * f_{t-j}{}^{(IV)} + \varepsilon_t$	1.99	19%	0.22 (0.079)	0.81* (0.072)		
$class\ I^{(reformed)} = \alpha + \beta_1 * f^{(III)} + \beta_2 * f^{(IV)} + \beta_3 * \Delta f_{t-j}^{(III)} + \beta_4 * \Delta f_{t-j}^{(IV)} + \varepsilon_t$	0.05	-98%	0.52* (0.013)	0.49* (0.013)	0.52 *(0.012)	0.45* (0.013)

*Note: Highlighted values are optimal hedge ratios; standard error in parentheses; *p-value<0.001*

Table 9. Class I Risk Management Evaluations Using Generalized Hedge Ratios for 30-day Hedge Intervals

30-day Models	$\sigma^2\|(x)$	$\Delta\sigma^2\|(x)$	β_1	β_2	β_3	β_4
$class\ I = \alpha + \beta_1 * f^{(max)} + \varepsilon_t$	0.11		1.04 (0.006)*			
$class\ I = \alpha + \beta_1 * f^{(max)} + \beta_2 * f_{t-j}^{(III)} + \varepsilon_t$	0.09	22%	0.1.03 (0.006)*	0.50 (0.068)*		
$class\ I = \alpha + \beta_1 * f^{(max)} + \beta_2 * f_{t-j}^{(IV)} + \varepsilon_t$	0.11	5%	1.04 (0.007)*	0.10 (0.038)*		
$class\ I = \alpha + \beta_1 * f^{(max)} + \beta_2 * f_{t-j}^{(max)} + \varepsilon_t$	0.06	47%	1.02 (0.005)*	0.63 (0.048)*		
$class\ I^{reformed} = \alpha + \beta_1 * f^{(III)} + \beta_2 * f^{(IV)} + \varepsilon_t$	0.10	9%	0.52 (0.015)*	0.51 (0.014)*		
$class\ I^{(reformed)} = \alpha + \beta_1 * f^{(III)} + \beta_2 * f^{(IV)} + \beta_3 * f_{t-j}^{(III)} + \beta_4 * f_{t-j}^{(IV)} + \varepsilon_t$	0.04	59%	0.52 (0.010)*	0.49 (0.010)*	0.28 (0.050)*	0.35 (0.025)*

*Note: Highlighted values are optimal hedge ratios; standard error in parentheses; *p-vale<0.001*

Conclusion

Significant basis risk resulted when cross-hedging Class I milk costs with Class III and IV futures under the previous Class I pricing formula. We find evidence that the newly reformed Class I milk price formula would reduce conditional variance on Class I cross hedges when using estimated optimal hedging ratios using techniques that have been established in the literature. This could have positive impacts to retailers and food service outlets that wish to have known costs for initiatives such as forecasting profits, innovating newly reformed Class I products, and planning promotions.

Under the previous Class I pricing formula, there was an asymmetry in basis risk between sellers of Class I milk and buyers who wish to hedge. We focused on the benefits to Class I milk buyers in this research, and more should be done to measure the consequences to sellers (such as farmers) of altering hedging basis with the reformed pricing formula.

The reformed Class I milk price has a fixed adjuster that is intended to compensate producers for having their skim milk price change from the higher of advance Class III and IV skim milk to the average of the two. We find evidence that this may not be an optimal compensatory mechanism for the formula change due to antipodal seasonal patterns between the volume of skim milk components sold and absolute spreads in the advance Class III-IV milk price. This results in a tendency for reformed Class I milk price to be more than the Class I milk price as calculated using the previous formula during times of the year when manufacturers are producing the most Class I skim milk.

We also measured slightly more stable uniform milk prices for all FMMOS, and higher Class I-utilizing areas, which inherently have more volatility, saw the greatest decline in uniform price variance. Years of low milk price were slightly boosted by the newly reformed Class I formula, and years of elevated milk price were slightly curtailed. We saw limited preliminary evidence that the newly reformed pricing formula would reduce incentives for manufacturing milk plants to de-pool, which would be a sign that the formula promotes orderly markets, a central tenant of the Federal Milk Marketing Order system.

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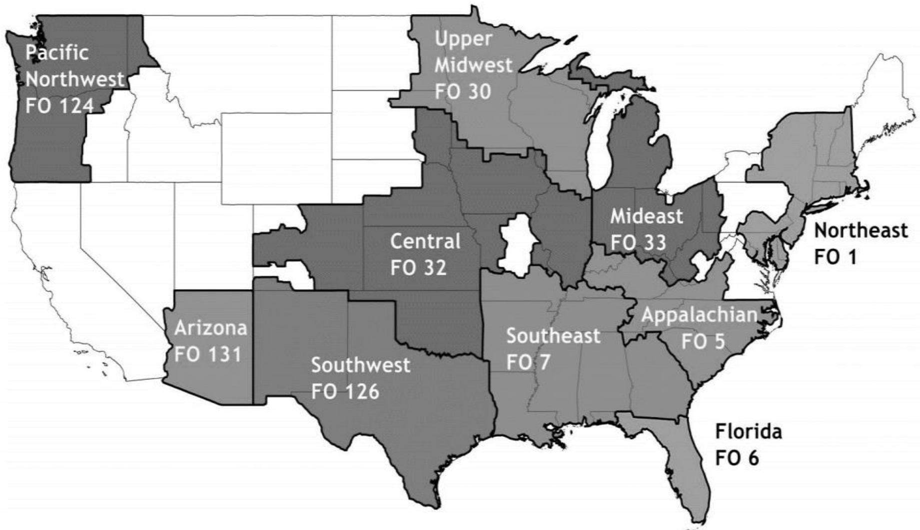
Appendix

Table 9. Previous – Reformed Class I Skim Milk Formula Prices, Full Dataset, Dollars per Hundredweights

Years	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
2000	-0.17	-0.50	-0.08	-0.01	0.32	0.47	0.86	-0.11	0.04	-0.19	-0.02	1.07	0.14
2001	0.94	0.77	0.51	0.29	0.43	0.08	-0.58	-0.54	-0.37	-0.70	0.43	-0.33	0.08
2002	-0.59	-0.62	-0.67	-0.28	-0.48	-0.53	-0.52	-0.19	-0.28	-0.61	-0.63	-0.33	-0.48
2003	-0.34	-0.51	-0.67	-0.47	-0.51	-0.74	-0.69	-0.18	1.02	1.50	1.43	1.10	0.08
2004	0.02	-0.43	-0.60	-0.58	1.99	2.65	1.57	-0.15	0.03	0.31	-0.06	0.14	0.41
2005	0.86	-0.09	0.69	0.02	0.38	0.04	0.11	-0.15	-0.53	-0.47	-0.21	-0.48	0.01
2006	-0.37	-0.22	-0.18	-0.52	-0.41	-0.54	-0.15	-0.32	-0.57	-0.06	-0.19	-0.49	-0.33
2007	-0.09	-0.18	0.08	0.01	-0.50	-0.32	-0.35	-0.66	0.30	0.03	0.60	-0.32	-0.12
2008	0.07	0.14	0.26	1.57	0.36	0.75	1.81	0.27	-0.20	-0.72	0.99	0.92	0.52
2009	1.86	-0.17	-0.62	-0.35	-0.13	-0.62	-0.58	-0.69	-0.50	-0.03	-0.23	-0.31	-0.20
2010	-0.61	-0.67	-0.29	-0.56	-0.32	0.32	0.20	0.36	-0.55	-0.44	-0.59	-0.42	-0.30
2011	-0.15	0.69	0.45	-0.59	0.88	1.29	0.80	-0.35	0.04	-0.36	-0.49	-0.67	0.13
2012	0.17	-0.59	-0.72	-0.59	-0.25	0.21	0.49	0.45	0.22	0.05	0.43	0.59	0.04
2013	-0.21	-0.49	-0.39	-0.34	-0.42	-0.58	-0.27	0.01	-0.12	-0.08	0.32	0.00	-0.21
2014	0.67	0.02	-0.65	-0.31	-0.20	-0.57	0.14	0.46	0.18	0.27	-0.08	1.24	0.10
2015	-0.03	0.82	0.25	-0.02	0.44	0.47	0.57	0.77	1.20	-0.34	-0.14	-0.04	0.33
2016	0.04	-0.52	-0.65	-0.23	-0.19	-0.67	-0.46	-0.67	0.30	0.43	-0.23	0.87	-0.16
2017	0.53	-0.44	-0.06	0.09	-0.12	-0.17	-0.44	0.00	-0.68	-0.48	-0.04	0.79	-0.08

Figure 1. Map of Federal Milk Market Orders (2017)



Source: AMS

Figure 2. Schematic of Class I Multiple Component Pricing Prior to Reform

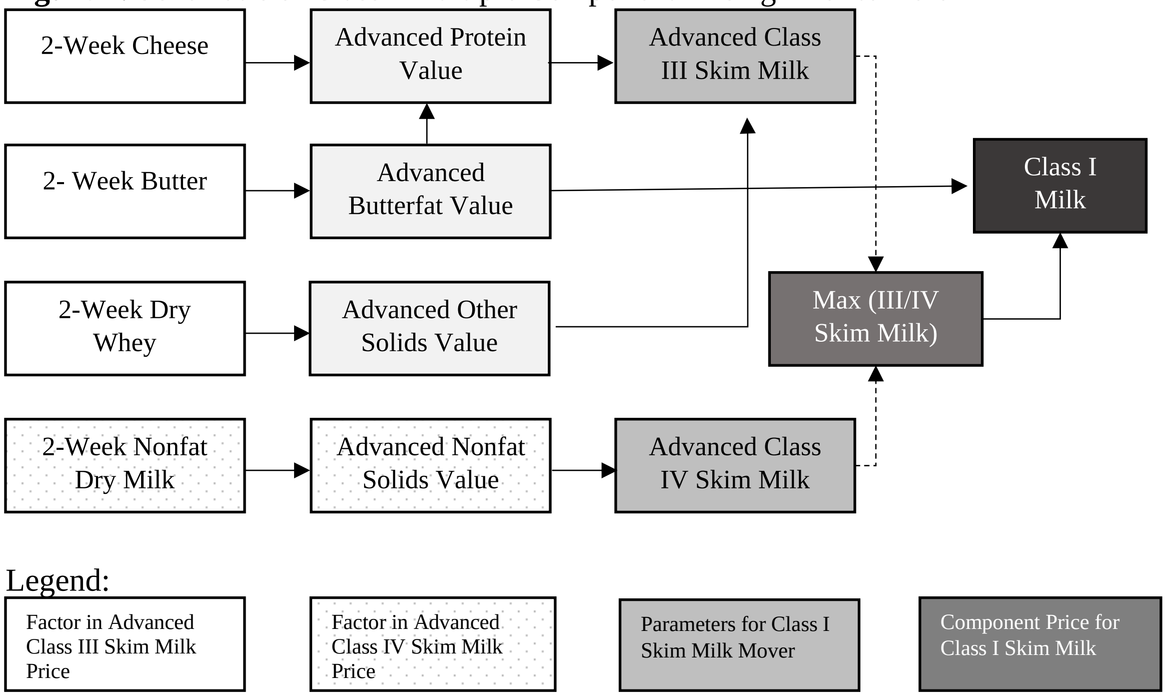


Figure 3. Schematic of Class I Multiple Component Pricing After Reform

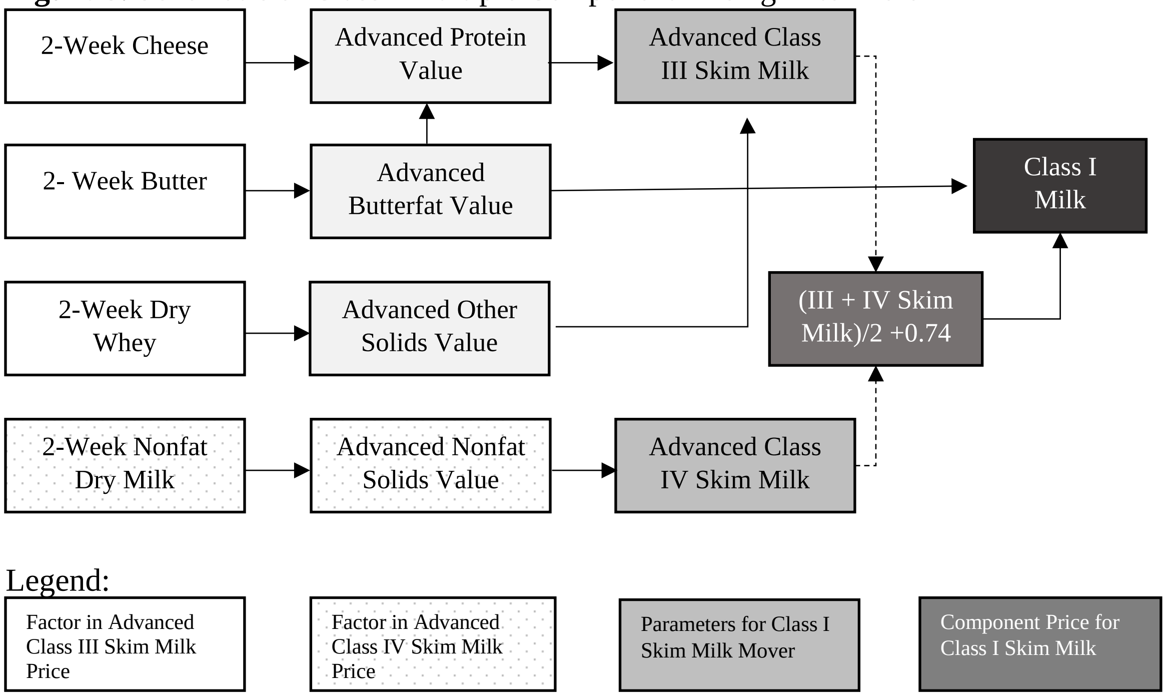


Figure 4. Index Effect: Basis Associated with Incorrectly Forecasting the Class I Mover

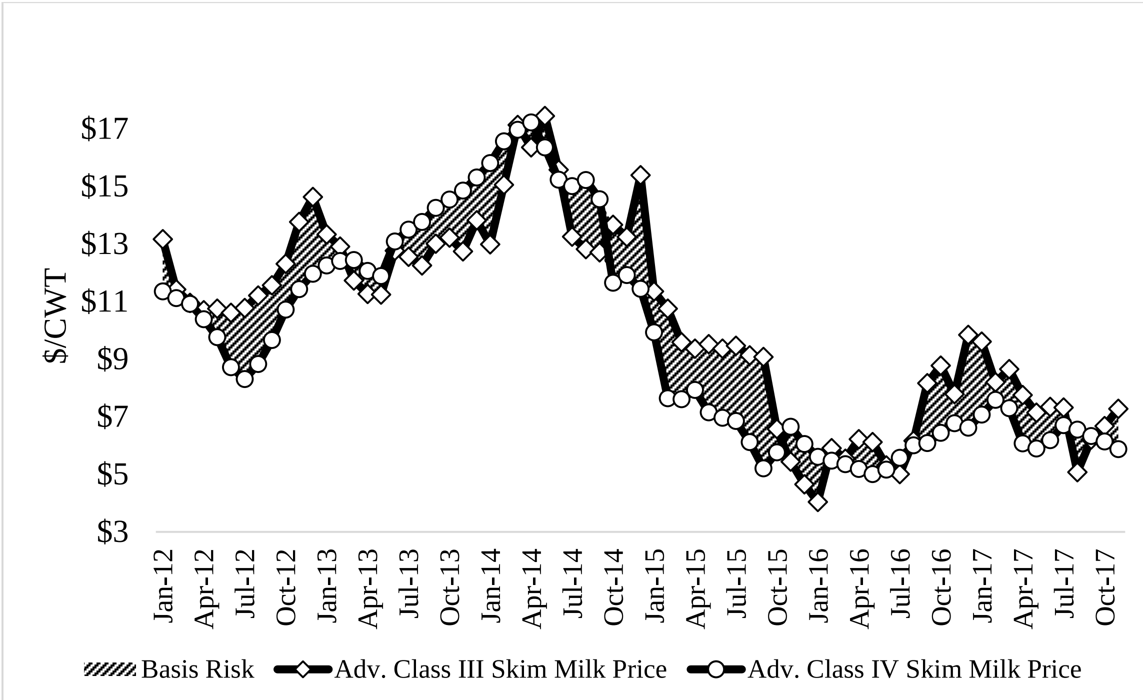
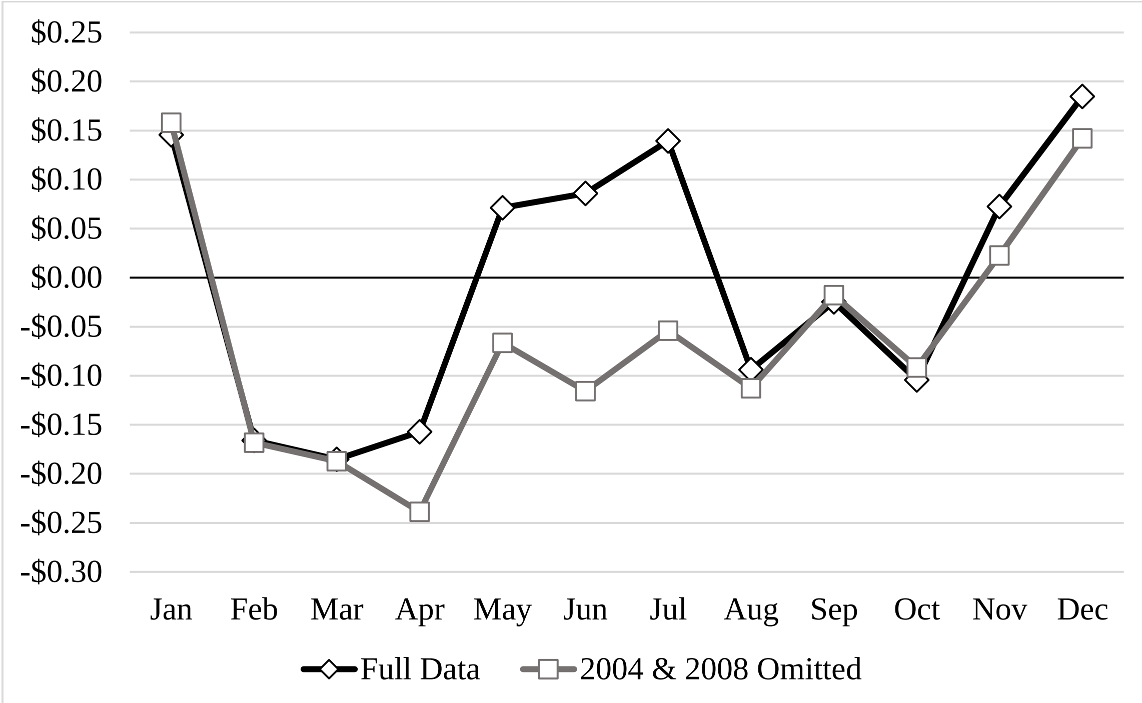


Figure 5. Seasonal Patterns of the Difference Between the Previous Class I Skim Milk Price and the Newly Reformed Class I Skim Milk Price



Points below zero indicate that the new skim milk pricing formula pays producers more than the previous formula.

Figure 6: Difference Between Previous and Reformed Advanced Class I Skim Milk Formula

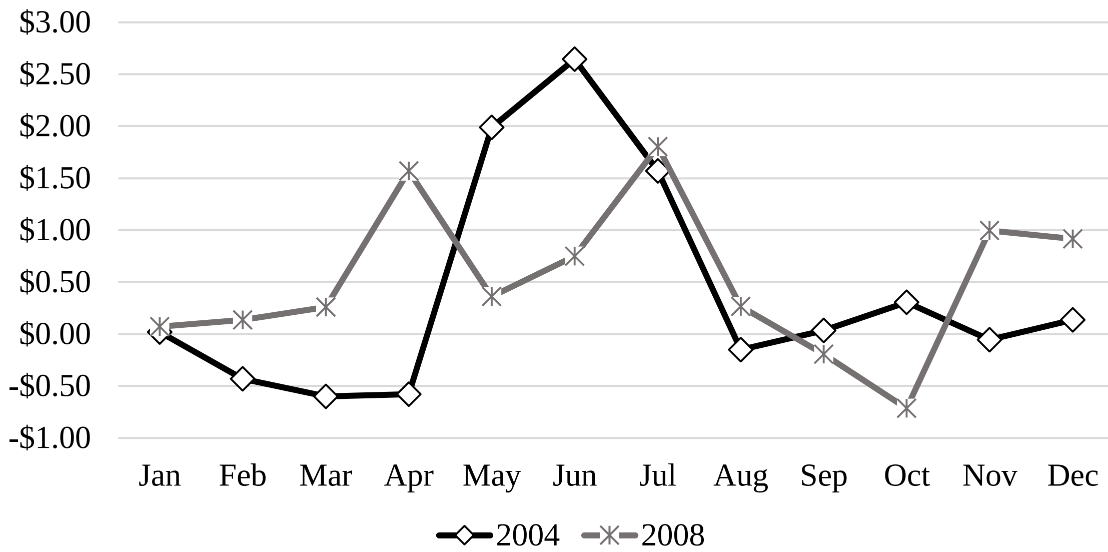


Figure 7. Class I Utilization and Standard Deviation of Uniform Prices

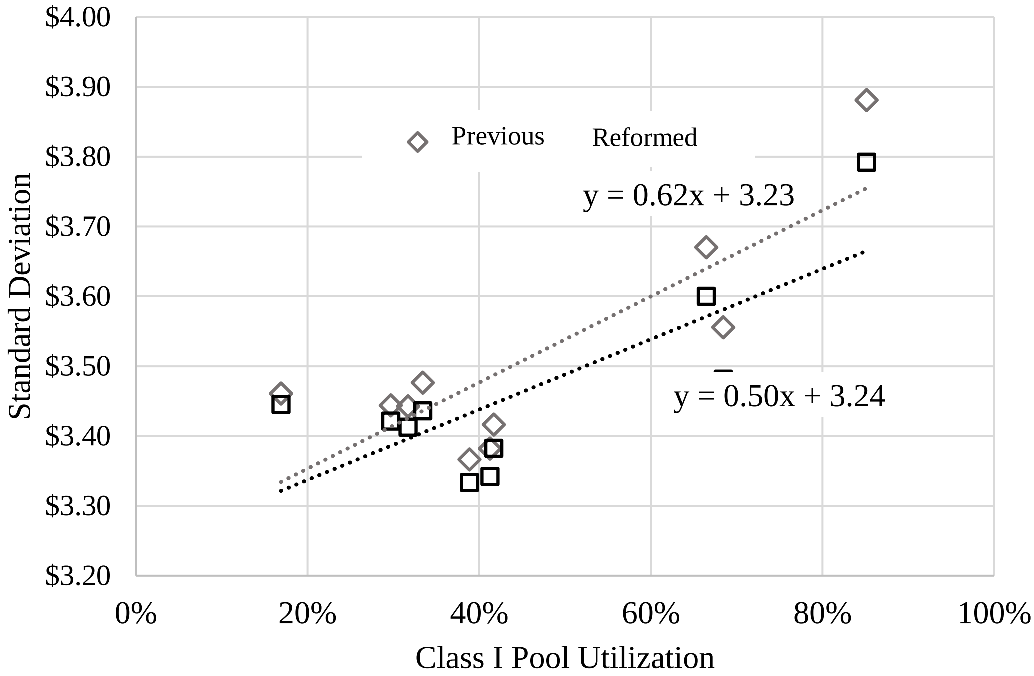


Figure 8. Reduction in Standard Deviation of Price based on FMMO Class I Utilization

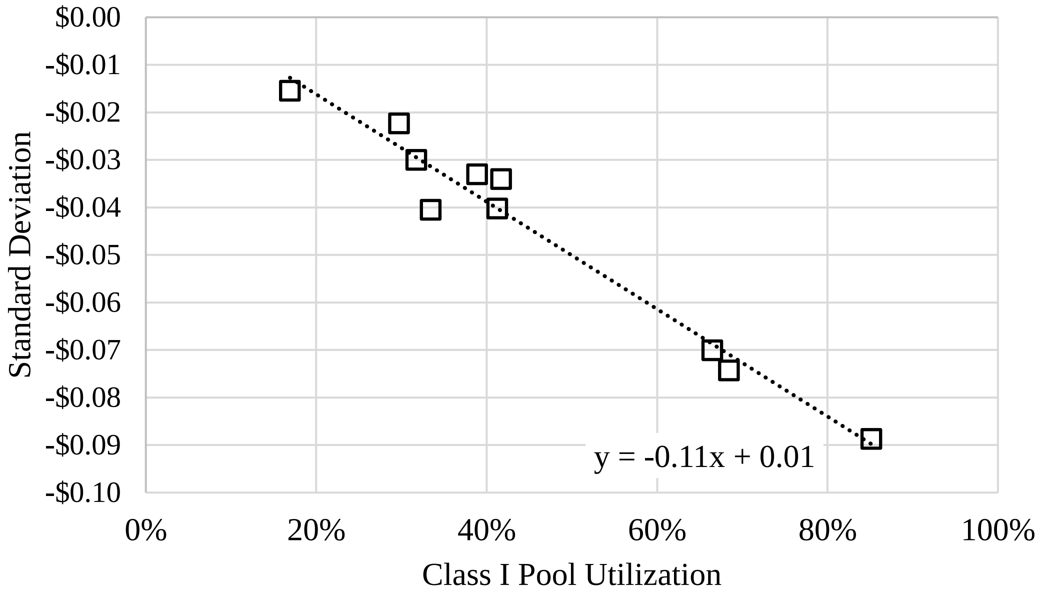


Figure 9. Basis When Hedging Previous Class I with Class IV Futures

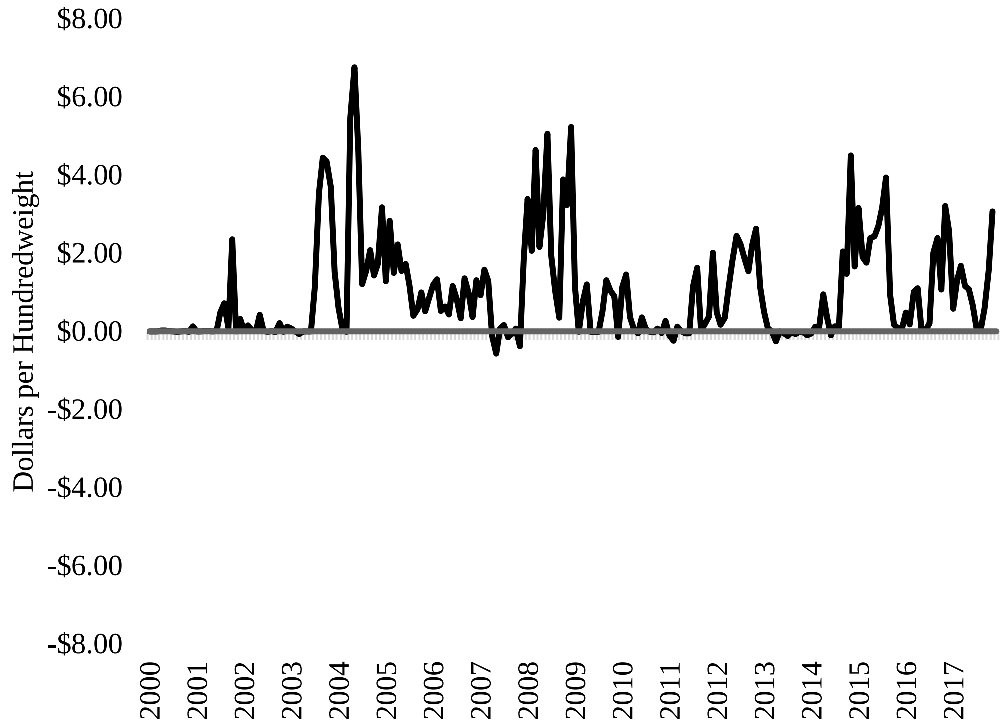


Figure 10. Basis When Hedging Previous Class I with Class III Futures

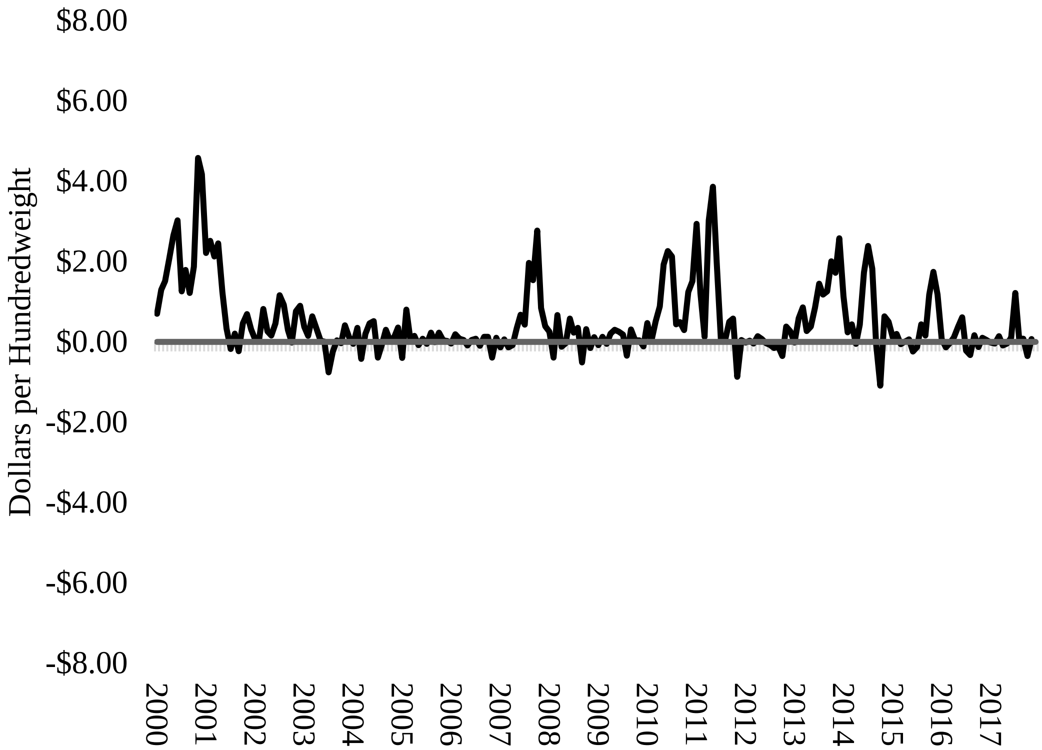


Figure 11. Basis When Hedging Class I with 50% Class III and 50% Class IV Futures, With Reformed Class I Pricing Formula

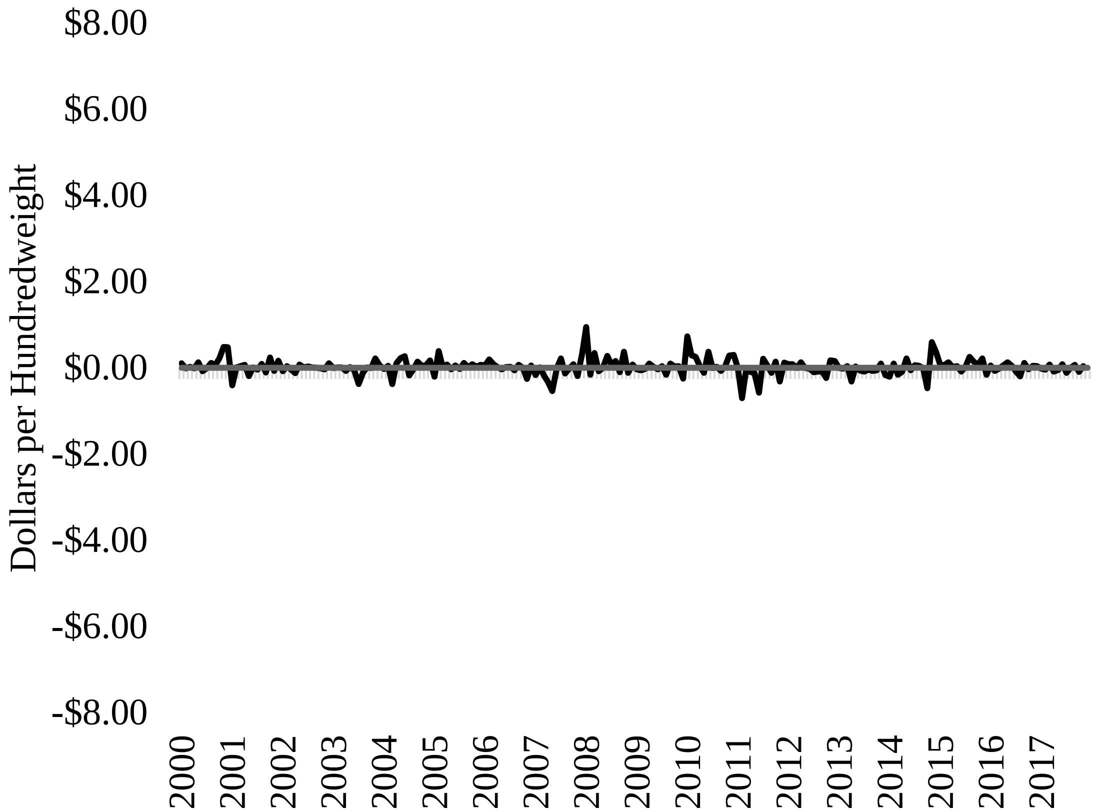


Figure 12. Measuring Difference Between Reformed Skim Milk Price and Class I Milk Price

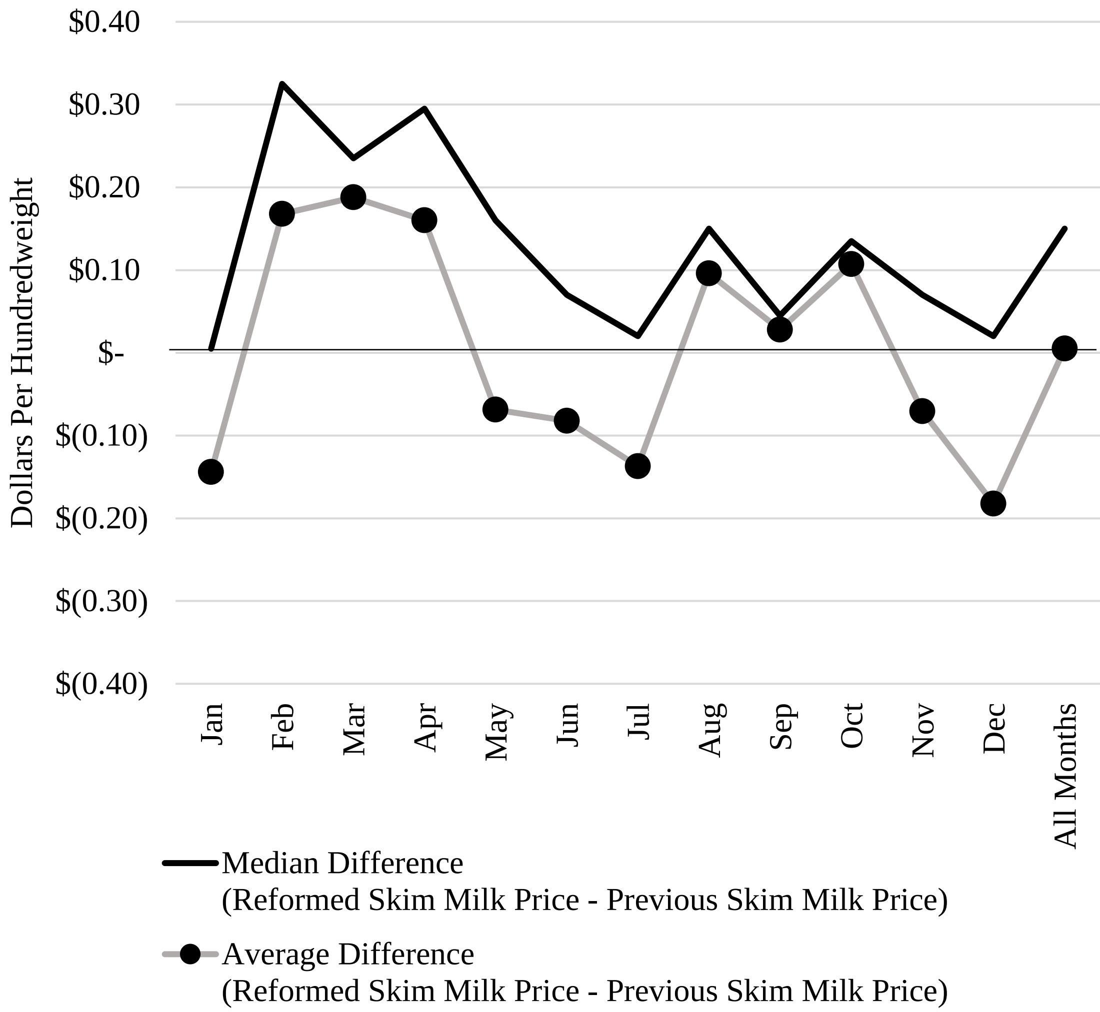


Figure 13. Seasonality in Milk Production and Historical Differences between Reformed and Previous Skim Milk Pricing Formula