DAIRY REVENUE PROTECTION INSURANCE:
EFFECT ON RISK REDUCTION AND RETURN

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by

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ABSTRACT

US farm milk prices have been volatile in recent years, prompting creation of several new risk management tools. The Dairy Revenue Protection Program is an agricultural insurance program that began operation in 2018 and has quickly become widely used. Dairy Revenue Protection is a subsidized basket of put options where dairy farmers can insure class III and class IV milk prices modified by deviations from trend in average milk per cow at the state level. This research examines the performance of Dairy Revenue Protection including the relative risk reduction provided, the mix of class III and IV prices, and the date of purchase. The results suggest that the program is effective in decreasing the negative semi-variance of milk price and that the variation across states is driven by the yield factor assigned to states.

Key words: price volatility, risk management tools, Dairy Revenue Protection, risk reduction

BIOGRAPHICAL SKETCH

Chengchen Ha is a second-year master's student at Cornell University majoring in Applied Economics and Management with a focus on Food and Agricultural Economics. Chengchen Ha was born in China and graduated from Chongqing University with an undergraduate degree in Energy Economics.

Chengchen Ha joined the research group supervised by Professor Huang Bo and Professor Wen-Chyuan Chiang in 2018 and initiated a project to find the optimally routing solution for package delivery using vehicles and UAVs that would save energy and reduce carbon emissions. The final result was presented in an academic paper entitled "Green Routing Problem of One Vehicle with Two UAVs," which won the prize at the fifth International Academic Symposium for College Students.

In 2019, Chengchen Ha joined NETEASE, one of the leading internet technology companies in China, as a strategic analyst intern. He took part in four product analyses in different industries. In 2020, Chengchen Ha joined in Huaxi Securities and Haitong Securities. He completed in-depth reports about companies in industries such as photovoltaic power, lithium batteries, and the photovoltaic device industry. Chengchen Ha also passed the China Securities Qualification Examination and China National Computer Rank Examination in 2020.

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Introduction

US farm milk price is composed of three parts: the Federal Milk Marketing Order uniform price which is a weighted average of class uses and utilizations, the cooperative or processor contract aspects including premiums and reblending, and farm specific aspects including component levels, quality and hauling cost.

The Federal Milk Marketing Orders (FMMO) are collective bargaining institutions created nearly a century ago in geographically defined regional fluid milk demand areas (Congressional Research Service, 2017). FMMO establishes minimum prices based on utilization. Class I includes fluid milk products (beverage milk). Class II includes milk used to make soft products (ice cream, cottage cheese, yogurt, etc.). Class III includes milk used to make hard cheese products. Class IV includes milk used to make butter and powdered dry milk products.

Over the past few decades, the US dairy industry has experienced increasing variability of milk prices, which is the main source of dairy farm revenue risk (Wolf, Black and Hadrich, 2009). To see the increasing volatility of US farm milk price, consider Figure 1, which clearly illustrates the increasing amount of variation in milk prices since 1995. The “all milk” price, including both grades A (fluid quality) and B (manufacturing quality) milk, is a weighted average of prices paid at the processing plants for farm milk (Wolf, 2012). Table 1 displays summary statistics for the US All Milk Price between 1990 and 2021, including the mean, standard deviation, and coefficient of variation. The coefficient of variation, a measure of volatility, is calculated as the standard deviation divided by the mean. The "all milk" prices had increasing coefficients of variation in the last 30-year period, from a coefficient of variation of 12% in the 1990 to 2005 period to a more volatile 17% in the 2006 to 2021 period. Therefore, it is obvious that the dairy farmers in the U.S. have been faced with more volatile milk prices since 2005.

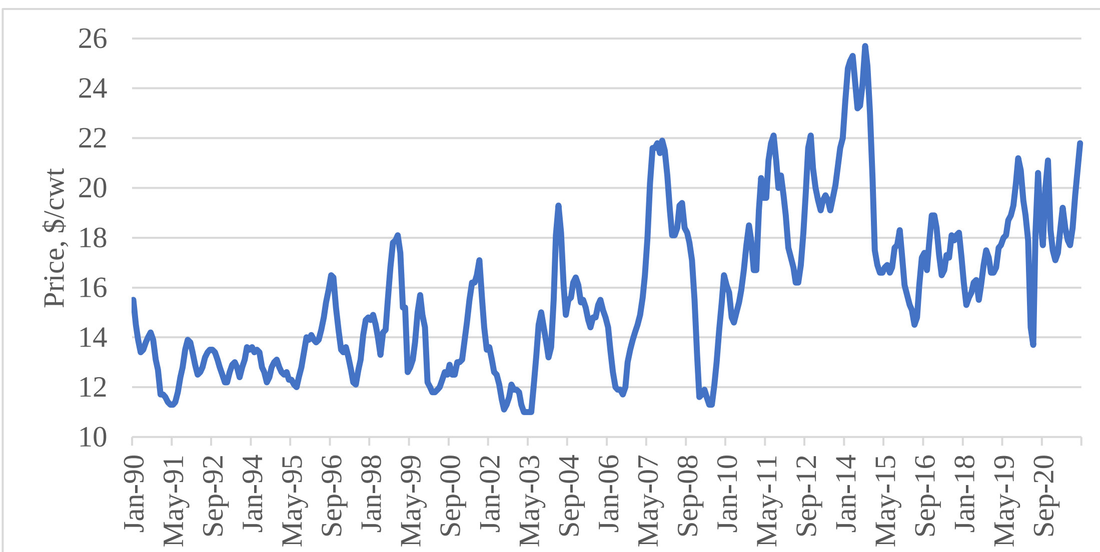

Figure 1: United States monthly all milk price, 1990 to 2021

Table 1: Level and variation of monthly US milk prices ($/cwt), 1990 to 2021

Time period	All milk price ($/cwt)		
	Mean	SD	CV
1990-2005	13.67	1.62	0.12
2006-2021	17.81	3.00	0.17

In response to this increased variability, dairy farmers are increasing their utilization of milk price risk management tools. One of the recent tools that has been made available is Dairy Revenue Protection (Dairy RP) insurance. Dairy RP is an insurance product that protects either class or component milk price on a quarterly basis. Dairy RP allows farmers to put a floor under the FMMO class III and IV portion of their milk price.

Previous research related to dairy farm milk price risk management tends to focus on how much milk to cover. In contrast, we examine strategies related to the two most common motivations for using Dairy RP including effects on risk reduction and expected average return. This study analyzes the performance of Dairy RP as a risk management tool in reducing risk and increasing average return, to reveal the best strategy of protecting dairy farmer's revenue. We calculate the risk-reducing potential of the Dairy RP program by comparing actual revenue when farmers do not buy Dairy RP with the actual gain when farmers buy Dairy RP since 2019 when Dairy RP started its coverage. Specifically, under the scenario of buying Dairy RP, we examine the risk reduction efficacy and average return of several strategies which depends on class price weighting factor and date of insuring. Results reveals the effectiveness of risk reduction by Dairy RP and identifies the best day to purchase this insurance. The data were collected from the database from Understanding Data & Markets website. Summary statistics of expected price, actual price, and premiums are included. The remainder of the paper begins with introduction to the existing dairy risk management tools and compares the difference and similarities between Dairy RP and these tools. A detailed introduction, including the mathematical description of Dairy RP is provided. The paper concludes with risk management recommendations.

Dairy Farm Milk Price Risk Management Tools

There are several tools available for managing farm milk price risk including forward contracts, futures, and options contracts. A brief discussion of these sets the stage for the Dairy Revenue Protection program that will be the focus of this research.

Forward Contracting

A forward contract is an agreement between a milk buyer and a dairy farmer or a cooperative association of dairy farmers. The dairy farmer or the cooperative sells a stated quantity of milk for a stated period in the future at a set price (USDA, 2019). Dairy farmers will receive the contract price no matter what the announced FMMO milk price becomes that month.

Futures Contracts

A futures contract is a contract traded on a futures exchange for the delivery of a specified commodity at a specified time and at a specified place of delivery or to cash settle the difference in price. Milk futures can be used to hedge in order to manage milk price fluctuations. A hedger is someone taking a position in the futures market that is equal and opposite to the position he either has or expects to take in the cash market. This position protects against adverse price movements (Anderson, et al., 1999).

Dairy-related futures contracts may be an effective risk management tool but are not widely used by farmers for several reasons. First, smaller producers may not have the ability to produce sufficient milk to cover a milk future contract for 2,000 hundredweight of milk in one month. Second, holding a futures market position requires the trader to maintain a margin account which represents a trader's equity. When futures prices move against a trader's open position, money is taken from the margin account to cover the losses, which requires more money to be added into the account to maintain equity. The notification a trader receives when a deposit to the margin account is required is known as a margin call (Anderson, 2000).

Moreover, hedging with futures contracts limits a trader's opportunity to benefit from price increases. Suppose that in March, a dairy farmer sells a September Milk contract at $18/cwt and current cash price for milk is $19/cwt. If the price of milk rises in September, the milk contract is trading for $20/cwt and the cash price of milk is $21/cwt. The $2/cwt gain in the cash market will be exactly offset by a $2/cwt loss in the futures market. Gains in one market will always be offset by losses in the other market as long as the difference between cash and futures prices, the basis, is constant. When prices go up, hedging with futures contracts will result in lower prices than could be realized in only the cash market.

Options Contracts

Options (puts and calls) are a derivative of futures contracts, which give farmers the right rather than obligation to purchase or sell a futures contract. Options can be traded without posting margin money unless and until the option is exercised. Options can also allow hedgers to establish a price floor without giving up the opportunity to benefit from favorable cash price changes. For milk, options contract can be purchased in a smaller size than the futures contract, with sizes of 1,000 cwt. The advantages that options contract possess help traders avoid negative aspects of futures market trading (Anderson, 2000).

General Description of Dairy RP

Designed by the American Farm Bureau Federation, American Farm Bureau Insurance Services and other collaborators, Dairy Revenue Protection (Dairy RP) is a revenue insurance program that aims to protect against the risk of unexpected declines in the revenue of dairy products every quarter, including unexpected declines in milk prices, unexpected declines in milk production, or both (Newton, 2017). Dairy RP was developed and approved through the Federal Crop Insurance Act's 508(h) process, which allows private parties to develop insurance products that are in the best interests of producers, follow sound insurance principles and are actuarially appropriate (Newton, 2018). The program went on sale on October 9, 2018 (coverage began during the first quarter of 2019) and is approved for sale in all counties in all 50 states.

In a Dairy RP contract, when the FMMO milk price occurs below the contract price, participants will receive a Dairy RP payment. Regardless of whether the announced price is higher or lower than the trigger price, the premium will be paid. But the dairy farmer still has the chance to benefit from the increasing market price, which is not available with forward contracting.

Dairy RP is similar to buying a bundle of put options which gains value when futures prices decline. The cost of the Dairy RP contract is the premium expressed in dollars per hundredweight, which is similar to the option price, but is subsidized by USDA. When using Dairy RP, producers know their premium risk at the time of purchase and do not have to be concerned about margin calls like they do when using dairy futures contracts. The premium of Dairy RP is due at the end of the covered quarter when indemnities are determined, which differs from put options, where the premium is due when the option is purchased.

Mechanism of Dairy RP

The Dairy RP policy provides insurance for the difference between the final revenue guarantee and covered actual milk revenue. Dairy RP uses the Chicago Mercantile Exchange (CME) futures market to set revenue guarantees in quarter blocks through the Risk Management Agency (RMA). This revenue guarantee locks in a milk price floor with a known risk and contract cost. There are four key decisions that need to be made under Dairy RP program.

Quarter

First, quarters for coverage are determined. Endorsements are only available for entire quarters. At any one time, sales are open for five future quarters. Sales close 15 days before the beginning of the insured quarter. Quarters are fixed for each year rather than just being any three consecutive months. Quarter 1 is January through March; Quarter 2 is April through June and so on.

Price Category

Second, to establish their revenue guarantees, dairy farmers select from two revenue pricing options. One is class pricing option which uses a weighted average of a three-month average of Chicago Mercantile Exchange Class III and Class IV milk futures prices based on the insured's declared class price weighting factor. The other one is component pricing option which uses the component milk prices for butterfat, protein, and other solids as a basis for determining coverage and indemnities. The component pricing option uses three-month averages of Chicago Mercantile Exchange butter, cheese, and dry whey futures to derive implied values for butterfat, protein, and other milk solids. The farmer then selects a component value of milk by declaring an amount of butterfat and protein in the milk. This would typically be the farms expected milk components production. This analysis focuses on the class pricing option which is the most common utilized to date.

Quantity

Third, dairy farmers choose the amount of milk they wish to protect. The Dairy RP program is designed to work for dairy farms of all sizes, so there is no minimum or maximum on the amount of milk farmers can insure under the program. The farmer's elected volume of milk will be indexed using average expected state milk yield per cow (Newton, 2017). For example, a farmer electing to insure 2 million pounds of milk with an expected state average milk yield of 4,000 pounds per cow would be covering the equivalent of 500 milking cows (2,000,000÷4,000 = 500). These animal unit equivalents would be used to determine the actual state-indexed milk production volume and actual revenue once USDA announced the final milk and component prices (Newton, 2017).

Meanwhile, farmers are obligated to produce at least 85% of the covered milk volume if Class III or IV coverage is chosen, or 90% of components covered if fat and protein coverages are chosen. When milk actually marketed during the quarter is below 85% of the declared covered production for the quarter, the amount of milk covered is determined by pounds of milk marketed for the quarter divided by 0.85.

Coverage Level

Finally, dairy farmers select between 80 and 95% of revenue coverage (in 5% increments) they wish to insure for the quarter. Like other agricultural insurance policies, USDA provides a premium discount to purchase Dairy RP and the discount would decrease as the farmer's elected coverage increases, as shown in Table 2.

Table 2: Coverage level and premium subsidy

Coverage level	80%	85%	90%	95%
Premium subsidy	55%	49%	44%	44%

Once the monthly milk and component prices are announced at the end of a quarter, and USDA's milk production report identifies the actual milk production per cow for each state, the state-indexed actual revenue is compared against the revenue guarantee, which is the product of the expected revenue and the coverage level selected by the farmer. If the actual revenue is below the guarantee, the farmer is paid a policy indemnity based on the difference. If the state-indexed actual revenue is above the revenue guarantee, the farmer pays the premium but receives no indemnity.

Mathematical Description of Dairy RP

Table 3 includes a summary of all the variables used in the analysis. At the end of the insurance period, the actual insurance indemnity is the difference, if positive, between the Per-cwt Guaranteed Revenue (PGR) and the Per-cwt Actual Revenue (PAR). Therefore, the Per-cwt indemnity is calculated as follows:

(1) PINDEM = max (PGR – PAR, 0)

Table 3: Abbreviation and description of variables used in Dairy RP model

Variable	Unit	Description
PER	$/cwt	Per-cwt expected revenue
PGR	$/cwt	Per-cwt guaranteed revenue
PAR	$/cwt	Per-cwt actual revenue
PINDEM	$/cwt	Per-cwt indemnity
CL	—	Coverage level
CPWF	—	Class price weighting factor
EC3P	$/cwt	Expected Class III price
EC4P	$/cwt	Expected Class IV price
AC3P	$/cwt	Actual Class III price
AC4P	$/cwt	Actual Class IV price
AY	lb.	Actual yield
EY	lb.	Expected yield

The PGR is Per-cwt Guaranteed Revenue determined at contract sign-up and is calculated using the Per-cwt Expected Revenue (PER) and a coverage level (CL). Similar to any insurance policy, the dairy farmer selects the portion of the PER not insured. Higher deductibles (lower CL) imply lower insurance premiums because it reduces potential insurance liability given lower indemnity probabilities and, if there are indemnities, the amounts are smaller. Suppose a dairy farmer chooses the maximum CL (95%), which means they receive a 44% premium subsidy. Therefore, PGR can be calculated as follows:

(2) PGR = PER * CL = [CPWF * EC3P + (1-CPWF) * EC4P] * CL

EC3P and EC4P represents the expected class III price and expected class IV price respectively, which are the average of the three contract month prices on the purchase date. The Class Price Weighting Factor (CPWF) means in class pricing option, how much weight farmers give to Class III milk price (1-CPWF is the weight given to Class IV price).

PGR is also the liability, which can be used to calculate the premium. The premium rate is based on the simulated losses under the class pricing option chosen. For example, suppose the premium rate is $0.025 per dollar of liability. Therefore, the per-cwt premium is calculated as 0.025*PGR.

Similar to PGR, PAR can be calculated with the following equation:

(3) PAR = [CPWF * AC3P + (1-CPWF) * AC4P] * (AY / EY)

AC3P and AC4P represents the actual class III price and actual class IV price, calculated as the simple average of the monthly settlement prices of the CME class III and class IV milk futures contract during the actual price measurement period.

In order to make this a revenue rather than a price insurance program, a yield adjustment factor is included. Dairy RP uses USDA quarterly milk production data to calculate an expected milk yield and a yield adjustment factor. Each quarter, once state-level milk production data has been announced by USDA, the yield adjustment factor is calculated. The yield adjustment factor is determined by dividing actual yield per cow (AY) by expected yield per cow (EY). Expected yield is based on historic trend milk per cow. Yield adjustment factors greater than one will increase the actual milk revenue and reduce any indemnity due to the dairy farmer. Likewise, a yield adjustment factor less than one will decrease the actual milk revenue and result in a greater indemnity.

Data and Analysis

Dairy RP has been available for purchase since October 9, 2018. The first quarter that dairy farmers could insure was then the first quarter of 2019 (i.e., January to March in 2019). As of the end of 2021, the latest actual yield data currently available was from the third quarter of 2021. Therefore, the time range of our data starts from the first quarter of 2019 to the third quarter of 2021, 11 quarters in total.

Tables 4 and 5 and Figures 2 and 3 display the actual Class III and IV price and summary statistics of expected Class III and IV price for each of the 11 quarters since the start of Dairy RP program sales.

Table 4: Actual Class III price and summary statistics of expected Class III price

Insurance Period	Expected Class III Price ($/cwt)			Actual Class III Price
	Mean	Median	SD	($/cwt)
2019Q1	15.06	15.09	0.43	14.30
2019Q2	15.48	15.53	0.32	16.20
2019Q3	16.42	16.34	0.28	17.82
2019Q4	16.77	16.46	0.53	19.51
2020Q1	16.52	16.43	0.59	16.77
2020Q2	16.67	16.75	0.50	15.42
2020Q3	16.94	17.14	0.84	20.25
2020Q4	17.00	17.11	0.61	20.22
2021Q1	16.35	16.28	0.55	15.98
2021Q2	16.62	16.49	0.59	17.95
2021Q3	17.46	17.08	0.93	16.32

Table 5: Actual Class IV price and summary statistics of expected Class IV price

Insurance Period	Expected Class IV Price ($/cwt)			Actual Class IV Price
	Mean	Median	SD	($/cwt)
2019Q1	15.03	15.03	0.11	15.68
2019Q2	15.86	15.72	0.32	16.28
2019Q3	16.66	16.70	0.46	16.66
2019Q4	16.87	16.87	0.45	16.56
2020Q1	16.95	17.00	0.30	15.91
2020Q2	17.18	17.33	0.61	11.66
2020Q3	16.88	17.62	1.82	13.01
2020Q4	16.48	17.52	1.74	13.38
2021Q1	15.39	15.06	1.19	13.71
2021Q2	15.73	15.57	0.87	15.98
2021Q3	16.31	16.28	0.52	16.09

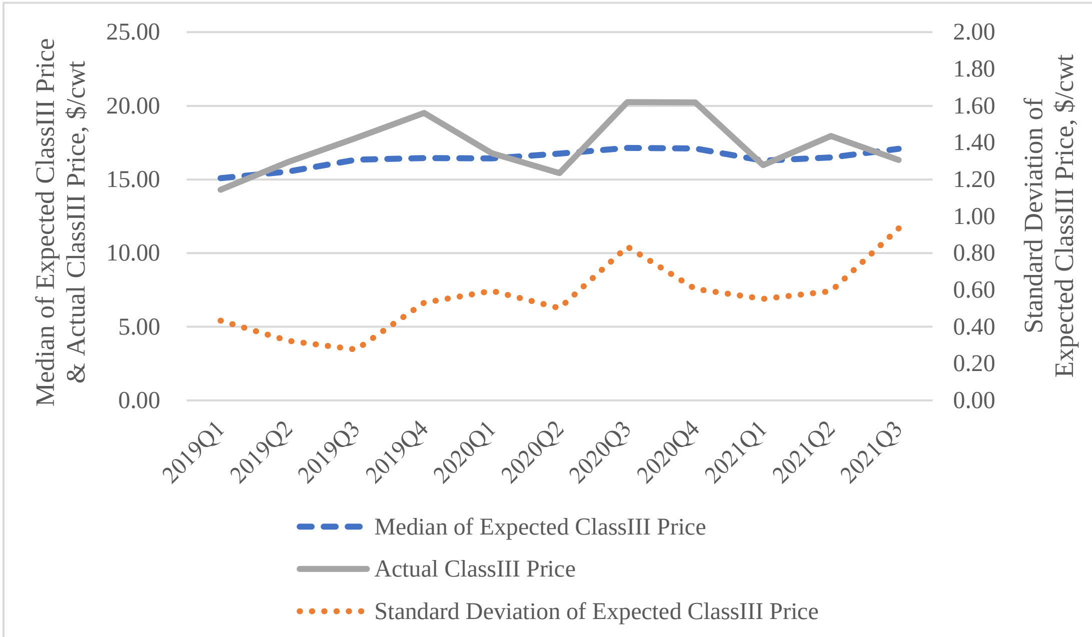

Figure 2: Actual Class III price and summary statistics of expected Class III price

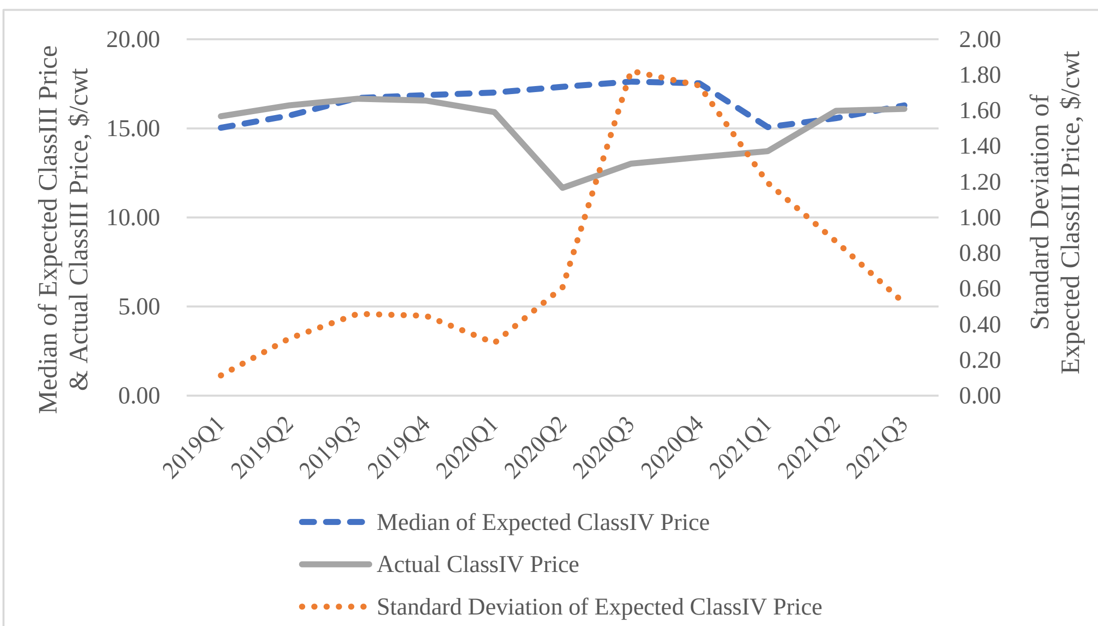

Figure 3: Actual Class IV price and summary statistics of expected Class IV price

The median of expected Class III price and expected Class IV price were largely similar in this period. The dispersion degree of expected Class III price generally shows a slight upward trend but remained low. In contrast, the dispersion degree of expected Class IV price fluctuated sharply. Although its standard deviation was generally stable throughout 2019, beginning with the second quarter of 2020, with the spread of COVID-19, the volatility of the expected Class IV price increased significantly. Actual Class III price mainly ranged from $15/cwt to $20/cwt and fluctuated within this range. Actual Class IV price mainly ranged from $13/cwt to $17/cwt. There was not much difference between these two prices in 2019 and 2021. In 2020, Class III price basically remained above $15/cwt, and even reached the level of $20/cwt. However, actual Class IV price experienced a huge drop in the first half of 2020 when it reached a low of $11.66/cwt, remaining below $15/cwt and not rebounding until the second quarter of 2021.

Combining the expected price and actual price, we find that the actual Class III price was not lower than the expected Class III price in most quarters, and the actual Class IV price was not higher than the expected Class IV price in most quarters. Dairy farmers only receive indemnities when the actual revenue is lower than the guaranteed revenue. Focusing on Class III price coverage, the probability of dairy farmers receiving indemnities was relatively low, in contrast to Class IV price coverage, where the probability of dairy farmers receiving compensation was relatively high. However, because farm selected coverage level and yield adjustment factor are not taken into consideration, this is a rough judgment. We analyze the specific situation through data on insurance premiums and indemnities in the following section.

Premiums differ across states because of the yield per cow component of the contract. For each of the examples of Dairy RP premiums below, a 44% premium subsidy associated with the 95% coverage level is assumed (the most common choices). Therefore, the following premiums are net premium (producer premium) which equals the total premium multiplying 56% after accounting for the subsidy.

Ignoring the abnormally high premiums in 2020 when the COVID-19 pandemic began in the U.S., in general, premiums under Dairy RP are more affordable for more nearby quarters than distant quarters. Premiums become more expensive for deferred insurance policies such as the fourth or fifth nearby quarter because the uncertainty (i.e., time value) in the market is higher. For example, as shown in Figures 4 and 5, based on data from October 9 and assuming a 95% coverage level and 100% class price weighting factor, producer premium rates in Wisconsin ranged from 10 cents per hundredweight for Quarter 1, 2019 to 25 cents per hundredweight for Quarter 4, 2019. In California, premiums for a similar policy and coverage periods ranged from 13 cents to 35 cents per hundredweight. Premiums are more affordable for the later quarters analyzed. That is because in the earlier quarters, uncertainty is higher. When approaching the end of the sales period, it is clearer to know whether farmers can receive an indemnity. Therefore, when eliminating the abnormally high premiums during 2020, premiums usually presented a decreasing trend from the first date to the last date that one quarter was available with the difference of \$0.20~0.30/cwt between peak and bottom value.

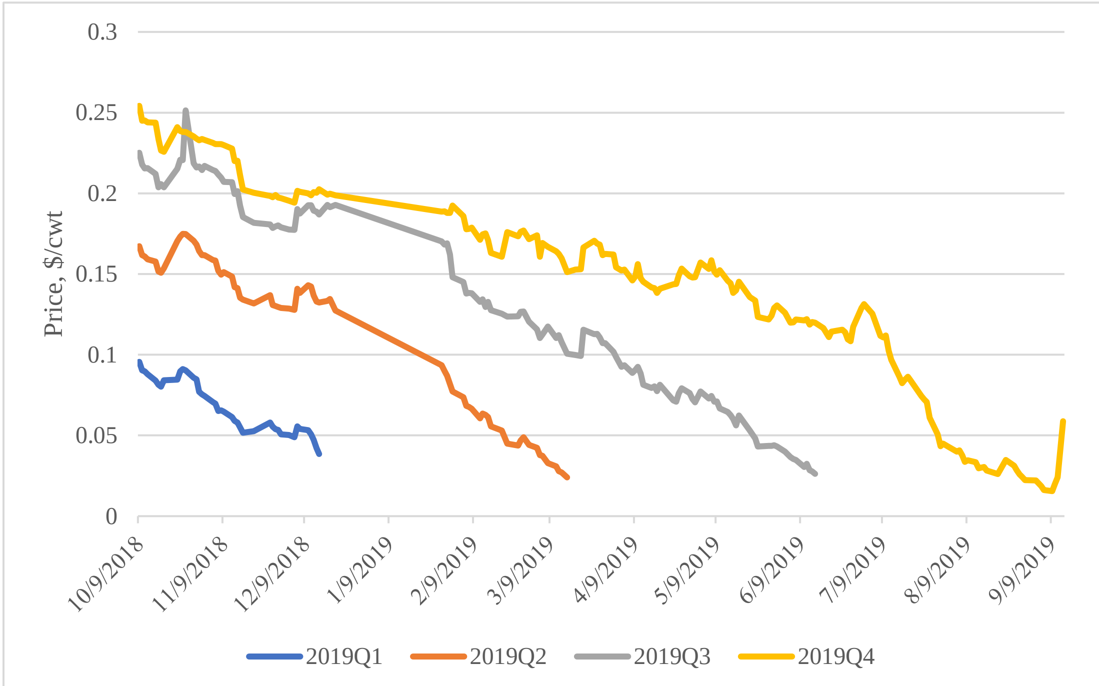

Figure 4: Premiums in 2019 (example of Wisconsin, Class III price fully insured)

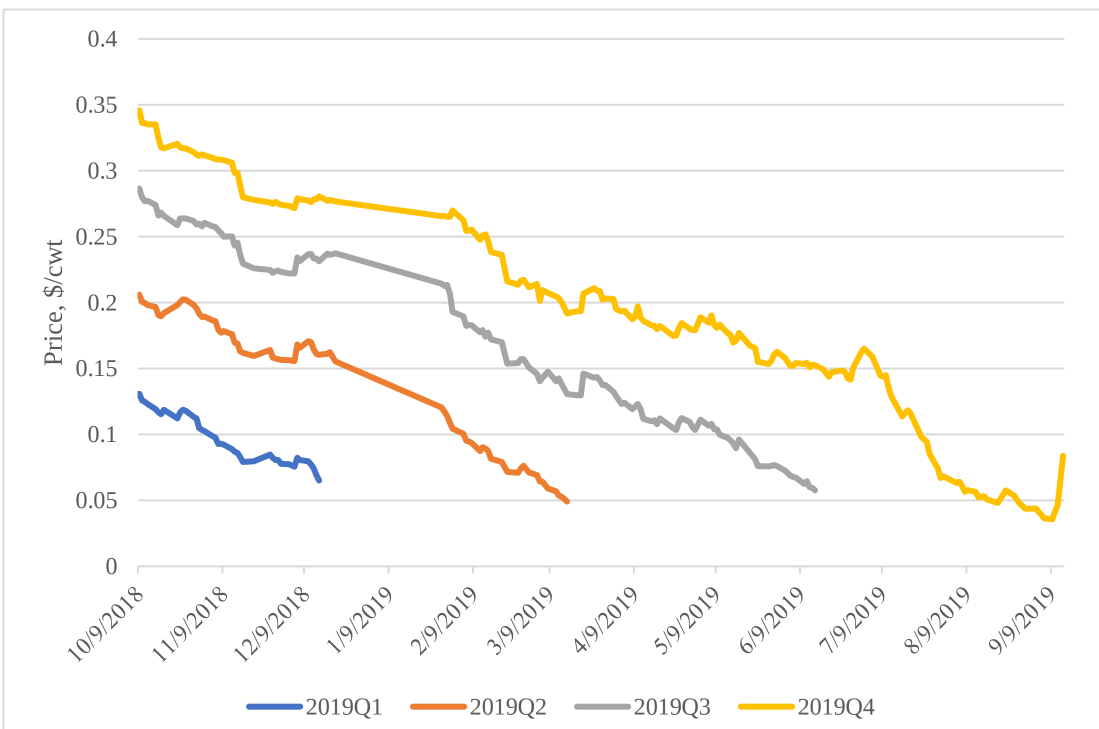

Figure 5: Premiums in 2019 (example of California, Class III price fully insured)

Obviously, if dairy farmers do not buy the Dairy RP insurance, they will receive the actual revenue (equation 3). Under Dairy RP program, the producer receives the actual revenue (equation 3) plus indemnities less premiums. Indemnities occur when actual revenue falls from higher expected levels during the life of a contract. That means participants can fail to receive indemnities even when actual revenue is low, if it is not below the expected value.

In terms of the long history of dairy risk management tools, it is important to understand the effectiveness of Dairy RP, which includes two objectives that farm managers may consider when purchasing. One objective is to reduce risk, which refers to whether buying Dairy RP can reduce risk for participating dairy farmers, to what extent it can reduce the risk, and what strategy have the best performance in risk reduction. The other objective is to increase average return, which refers to whether buying Dairy RP can increase dairy farmers' return, and what strategy will give participants the best return from using Dairy RP. In an efficient market risk should be reduced but at a cost and thus a lower expected return. However, because the premium is subsidized by the government there is a transfer from taxpayers to farmers. Therefore, this two objectives can be combined and achieved.

As far as risk reduction is concerned, to compare of revenue distributions with and without Dairy RP, we use root mean squared downside deviations from the median as the measure of risk (Burdine, K. H., et al., 2014). That is,

$$risk = \left(\frac{1}{2I}\sum_{1\le i\le I}[Q_i < \mu](\mu - Q_i)^2\right)^{1/2}$$

where Q_i is the actual revenue (without Dairy RP)/actual revenue plus indemnities less premiums (with Dairy RP) corresponding to the insured quarter i. For these calculations, the capital letter I equals 8 and i ranges from 1 to 8 (there are 8 quarters which had complete sales period up to 5 quarters from 2019Q4 to 2021Q3). μ is the median value of 8 quarterly actual revenue (without Dairy RP)/actual revenue plus indemnities less premiums (with Dairy RP). Instead of using mean, we use deviations from the median, because mean may be affected by extreme high or low values when the distribution is skewed. Although variance is a convenient and commonly used measure of risk (e.g., Chavas and Holt, 1990), there is no reason to expect revenue distributions to be symmetric (Burdine, K. H., et al., 2014). More importantly, dairy farmers are sensitive to a milk price decline, so the downside deviation better reflects this risk.

Within the option of buying Dairy RP insurance, there are several strategies among which the selection of class price weighting factor and the date of buying Dairy RP are most critical. After collecting data on the Dairy RP program from the Understanding Data & Markets website, the selection of class price weighting factor is divided into three groups—1, 0.5, and 0. Class price weighting factor represents how much weight farmers give to Class III price. Therefore, its value equaling to one means focusing exclusively on Class III milk price coverage, while 0 means focusing on Class

IV milk price coverage and 0.5 means half to half. We would expect farms to select a weighting factor that is related to the expected weights of Class III and IV milk in their marketing order. For example, farmers in Wisconsin would likely use Class III almost exclusively as most milk in the Upper Midwest marketing order is used for cheese. By examining this range of weights, we consider both extremes as well as the average. As for the date of buying Dairy RP, we examine 180 dates (from the 1st date to the 180th date) of the sales period of each quarter (from 2019Q4 to 2021Q3) in order to find the best date that had the highest risk reduction effect and the highest average return.

Summary statistics of the risk reduction in 50 states during 180 days are in display in Table 6. Results of major milk producing states and extremum from the risk reduction effect analysis are displayed in Figures 6, 7, and 8.

Table 6: Summary statistics of risk reduction in 180 days (50 states)

State	CPWF = 1			CPWF = 0.5			CPWF = 0		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Alabama	54%	12%	24%	85%	37%	56%	81%	1%	41%
Alaska	32%	-3%	9%	58%	40%	48%	76%	-9%	44%
Arizona	48%	12%	29%	81%	37%	55%	93%	7%	51%
Arkansas	54%	12%	24%	85%	37%	56%	81%	1%	41%
California	30%	0%	10%	56%	40%	47%	75%	-10%	42%
Colorado	50%	4%	21%	78%	35%	52%	90%	-6%	47%
Connecticut	45%	-5%	16%	73%	38%	52%	93%	-1%	50%
Delaware	45%	-1%	16%	73%	38%	52%	93%	-1%	50%
Florida	63%	0%	18%	70%	38%	50%	64%	-5%	33%
Georgia	54%	12%	24%	85%	37%	56%	81%	1%	41%
Hawaii	32%	-3%	9%	58%	40%	48%	76%	-9%	44%
Idaho	40%	-5%	15%	69%	38%	51%	89%	-7%	44%
Illinois	43%	-6%	8%	58%	40%	48%	88%	4%	47%
Indiana	37%	-4%	10%	75%	42%	53%	97%	-9%	47%
Iowa	46%	-6%	18%	71%	43%	55%	85%	-4%	40%
Kansas	45%	-5%	17%	64%	40%	52%	90%	1%	46%
Kentucky	45%	-5%	8%	67%	37%	49%	93%	-12%	46%
Louisiana	54%	12%	24%	85%	37%	56%	81%	1%	41%
Maine	45%	-1%	16%	73%	38%	52%	93%	-1%	50%
Maryland	45%	-1%	16%	73%	38%	52%	93%	-1%	50%
Massachusetts	45%	-1%	16%	73%	38%	52%	93%	-1%	50%
Michigan	51%	-1%	23%	76%	47%	57%	83%	-2%	43%
Minnesota	41%	-7%	12%	62%	44%	50%	92%	1%	43%
Mississippi	54%	12%	24%	85%	37%	56%	81%	1%	41%
Missouri	44%	-5%	13%	70%	43%	53%	92%	-1%	45%
Montana	47%	0%	20%	71%	38%	53%	89%	-1%	46%
Nebraska	46%	-1%	20%	72%	40%	54%	86%	0%	46%
Nevada	47%	0%	20%	71%	38%	53%	89%	-1%	46%
New Hampshire	45%	-1%	16%	73%	38%	52%	93%	-1%	50%
New Jersey	45%	-1%	16%	73%	38%	52%	93%	-1%	50%
New Mexico	63%	9%	29%	68%	40%	52%	64%	1%	35%
New York	42%	7%	24%	78%	38%	53%	87%	8%	52%
North Carolina	45%	-5%	8%	67%	37%	49%	93%	-12%	46%
North Dakota	46%	-1%	20%	72%	40%	54%	86%	0%	46%
Ohio	56%	-4%	15%	68%	40%	52%	85%	0%	40%
Oklahoma	55%	-5%	16%	61%	33%	47%	80%	-2%	42%
Oregon	38%	-4%	11%	66%	42%	52%	96%	2%	49%
Pennsylvania	45%	-4%	9%	68%	36%	48%	95%	-4%	49%
Rhode Island	45%	-1%	16%	73%	38%	52%	93%	-1%	50%

Table 6 (continued)

South Carolina	54%	12%	24%	85%	37%	56%	81%	1%	41%
South Dakota	40%	-5%	15%	71%	41%	52%	94%	6%	51%
Tennessee	45%	-5%	8%	67%	37%	49%	93%	-12%	46%
Texas	56%	-4%	15%	59%	33%	46%	77%	2%	41%
Utah	44%	10%	31%	83%	42%	55%	76%	3%	45%
Vermont	45%	9%	26%	72%	36%	53%	80%	2%	46%
Virginia	55%	-5%	12%	63%	38%	50%	82%	-11%	40%
Washington	52%	-6%	16%	59%	40%	49%	80%	-9%	38%
West Virginia	45%	-5%	8%	67%	37%	49%	93%	-12%	46%
Wisconsin	38%	1%	22%	72%	40%	53%	85%	5%	49%
Wyoming	47%	0%	20%	71%	38%	53%	89%	-1%	46%

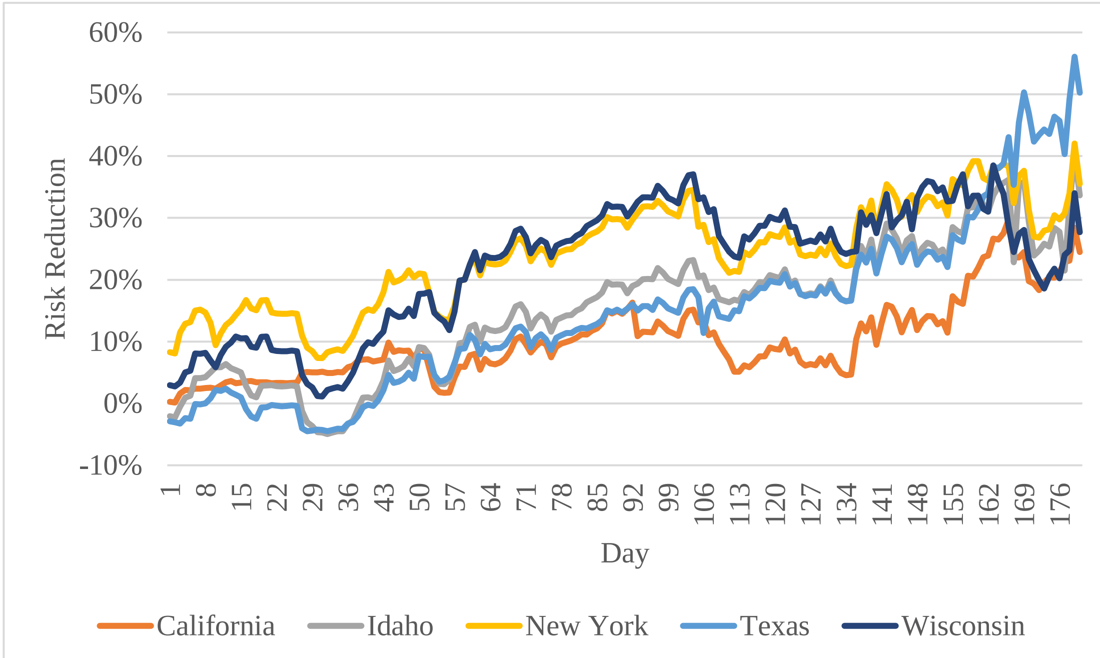

Figure 6: Risk reduction effect (Class price weighting factor = 1)

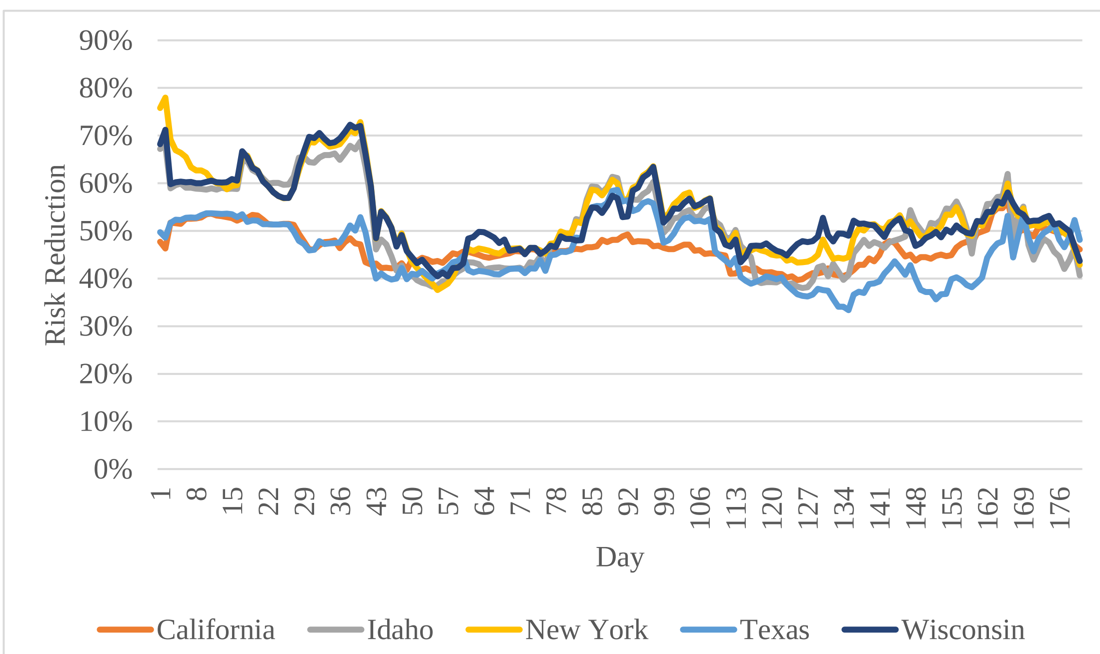

Figure 7: Risk reduction effect (Class price weighting factor = 0.5)

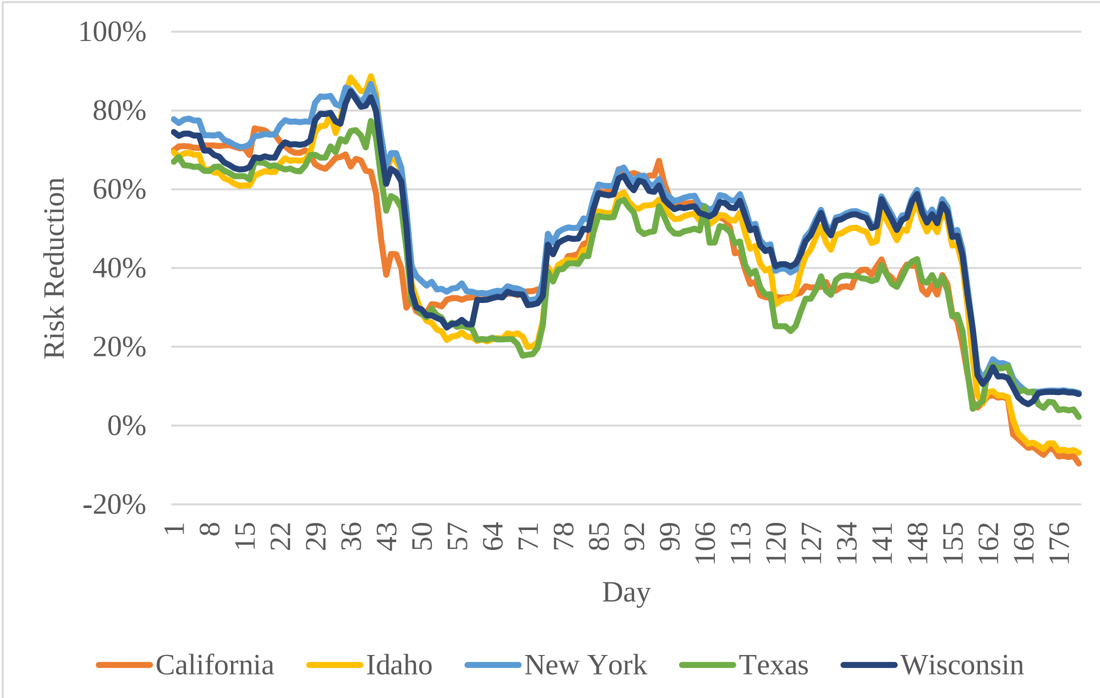

Figure 8: Risk reduction effect (Class price weighting factor = 0)

Most of the curves are above 0%, which suggest that Dairy RP was effective in most states in reducing the risk faced by dairy producers during the vast majority of the sales period. Milk price risk, as measured by the downside semi-variance of revenue, was considerably smaller under Dairy RP participation than in its absence. Figure 6 shows risk reduction levels when fully insuring on Class III price. Although the extent of risk reduction varied across states,[1] we still find the best day to buy Dairy RP for risk

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[1] As for the reason for the variation, the only difference across 50 states are premiums and yield adjustment factor (actual yield/expected yield). Assumed no premiums or equal premiums, variation across states still exists. When we assume there was no yield adjustment factor, curves without yield adjustment factor were more gathered together, especially in risk reduction. That revealed that without yield adjustment factor, the great variation across states did not exist anymore. In other words, different yield adjustment factors in each states made the risk reduction effect and change in average return so different from each other.

reduction was the last day of the sales period, when risk reduction effect was over 60% maximum. Figure 7 shows risk reduction levels when insuring 50% each on Class III price and Class IV price. We can find that the best day to buy Dairy RP for risk reduction was generally the first day. Figure 8 shows risk reduction levels when fully insuring on Class IV price. In this scenario, the best day to buy Dairy RP for risk reduction was generally around the 40th day of the sales period, when risk reduction effect was over 90% maximum. Although one must keep in mind the limited number of quarters analyzed here given the relatively young age of this program. Moreover, the sales period begins each day by 4:30 PM Central time and ends at 9:00 AM Central time of the following business day in which farmers purchase quarterly endorsements. Therefore, it should be optimal to wait until the last minute of the day (9:00 AM Central time) to make decision because more information may become available. The following suggestions apply the same caveats.

After analyzing the risk reduction efficacy, we consider the change in average return when buying Dairy RP, which is also a critical concern for dairy farmers. Summary statistics of the change in average return in 50 states during 180 days in included in Table 7. Results of main states and extremum from the analysis of change in average return are displayed in Figures 9, 10, and 11.

Table 7: Summary statistics of change in average return in 180 days (50 states)

State	CPWF = 1			CPWF = 0.5			CPWF = 0		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Alabama	1.3%	-1.2%	-0.6%	2.8%	0.4%	1.5%	13.7%	7.2%	10.3%
Alaska	0.5%	-1.7%	-1.1%	1.6%	-0.5%	0.4%	9.5%	5.8%	7.8%
Arizona	1.0%	-1.1%	-0.5%	2.8%	0.9%	1.7%	12.6%	7.5%	10.5%
Arkansas	1.3%	-1.2%	-0.6%	2.8%	0.5%	1.5%	13.7%	7.2%	10.3%
California	0.4%	-1.8%	-1.1%	1.5%	-0.5%	0.3%	9.1%	5.7%	7.4%
Colorado	1.0%	-1.2%	-0.5%	3.2%	1.2%	2.1%	14.0%	6.6%	11.4%
Connecticut	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%
Delaware	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%
Florida	1.3%	-1.7%	-0.8%	2.6%	0.0%	1.1%	11.6%	6.8%	9.2%
Georgia	1.3%	-1.2%	-0.6%	2.8%	0.5%	1.5%	13.7%	7.2%	10.3%
Hawaii	0.5%	-1.7%	-1.1%	1.6%	-0.5%	0.4%	9.5%	5.8%	7.8%
Idaho	1.0%	-1.5%	-0.7%	2.5%	0.2%	1.3%	12.2%	7.1%	10.2%
Illinois	0.5%	-1.5%	-0.9%	1.4%	-0.2%	0.6%	10.0%	6.1%	8.4%
Indiana	0.8%	-1.7%	-1.0%	2.0%	-0.2%	0.8%	11.5%	6.8%	9.6%
Iowa	1.1%	-1.4%	-0.7%	2.6%	0.1%	1.2%	11.9%	7.2%	9.9%
Kansas	1.1%	-1.4%	-0.6%	2.3%	0.2%	1.2%	11.5%	7.0%	9.6%
Kentucky	0.6%	-1.5%	-0.9%	1.7%	-0.1%	0.9%	11.3%	6.5%	9.4%
Louisiana	1.3%	-1.2%	-0.6%	2.8%	0.5%	1.5%	13.7%	7.2%	10.3%
Maine	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%
Maryland	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%
Massachusetts	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%
Michigan	1.3%	-1.2%	-0.5%	2.7%	0.3%	1.5%	12.4%	7.3%	10.4%
Minnesota	1.0%	-1.4%	-0.7%	2.3%	0.0%	1.0%	10.9%	7.0%	9.3%
Mississippi	1.3%	-1.2%	-0.6%	2.8%	0.5%	1.5%	13.7%	7.2%	10.3%
Missouri	0.9%	-1.5%	-0.8%	2.1%	0.0%	0.9%	11.3%	6.9%	9.4%
Montana	1.3%	-1.3%	-0.6%	2.8%	0.3%	1.4%	12.1%	7.3%	10.2%
Nebraska	1.2%	-1.4%	-0.5%	2.6%	0.3%	1.5%	12.4%	7.3%	10.4%
Nevada	1.3%	-1.3%	-0.6%	2.8%	0.3%	1.4%	12.1%	7.3%	10.2%
New Hampshire	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%
New Jersey	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%
New Mexico	1.9%	-0.9%	0.1%	3.3%	0.8%	2.0%	12.0%	7.6%	10.2%
New York	0.9%	-1.2%	-0.5%	2.6%	1.1%	1.9%	13.4%	7.3%	11.0%
North Carolina	0.6%	-1.5%	-0.9%	1.7%	-0.1%	0.9%	11.3%	6.5%	9.4%
North Dakota	1.2%	-1.4%	-0.5%	2.6%	0.3%	1.5%	12.4%	7.3%	10.4%
Ohio	0.9%	-1.5%	-0.8%	1.9%	0.0%	0.9%	11.1%	6.4%	9.1%
Oklahoma	1.4%	-1.4%	-0.6%	2.6%	0.1%	1.2%	10.7%	6.7%	8.9%
Oregon	0.5%	-1.6%	-0.9%	1.7%	-0.2%	0.8%	11.1%	6.8%	9.3%
Pennsylvania	0.7%	-1.3%	-0.8%	1.6%	0.1%	0.9%	10.9%	6.3%	9.1%
Rhode Island	0.9%	-1.4%	-0.7%	2.0%	0.4%	1.2%	12.0%	6.8%	10.0%

Table 7 (continued)

South Carolina	1.3%	-1.2%	-0.6%	2.8%	0.5%	1.5%	13.7%	7.2%	10.3%
South Dakota	0.9%	-1.4%	-0.7%	2.1%	0.2%	1.2%	11.9%	6.9%	9.8%
Tennessee	0.6%	-1.5%	-0.9%	1.7%	-0.1%	0.9%	11.3%	6.5%	9.4%
Texas	1.3%	-1.4%	-0.6%	2.5%	0.0%	1.1%	10.4%	6.7%	8.7%
Utah	1.5%	-0.9%	-0.1%	3.5%	1.3%	2.5%	14.5%	8.1%	11.9%
Vermont	1.3%	-1.2%	-0.3%	3.2%	1.2%	2.4%	13.6%	7.7%	11.5%
Virginia	0.9%	-1.4%	-0.7%	2.3%	0.1%	1.1%	11.5%	6.4%	9.6%
Washington	1.1%	-1.5%	-0.7%	2.2%	-0.1%	1.1%	11.3%	6.7%	9.5%
West Virginia	0.6%	-1.5%	-0.9%	1.7%	-0.1%	0.9%	11.3%	6.5%	9.4%
Wisconsin	1.0%	-1.3%	-0.5%	2.7%	0.7%	1.8%	13.0%	7.5%	11.0%
Wyoming	1.3%	-1.3%	-0.6%	2.8%	0.3%	1.4%	12.1%	7.3%	10.2%

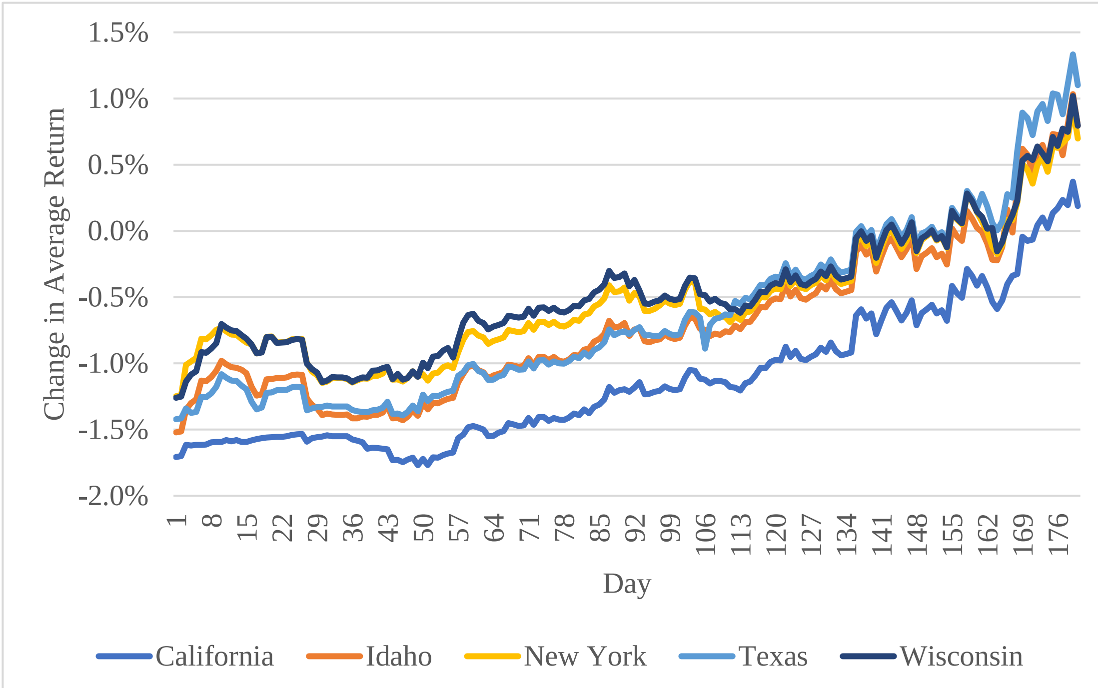

Figure 9: Change in average return (Class price weighting factor = 1)

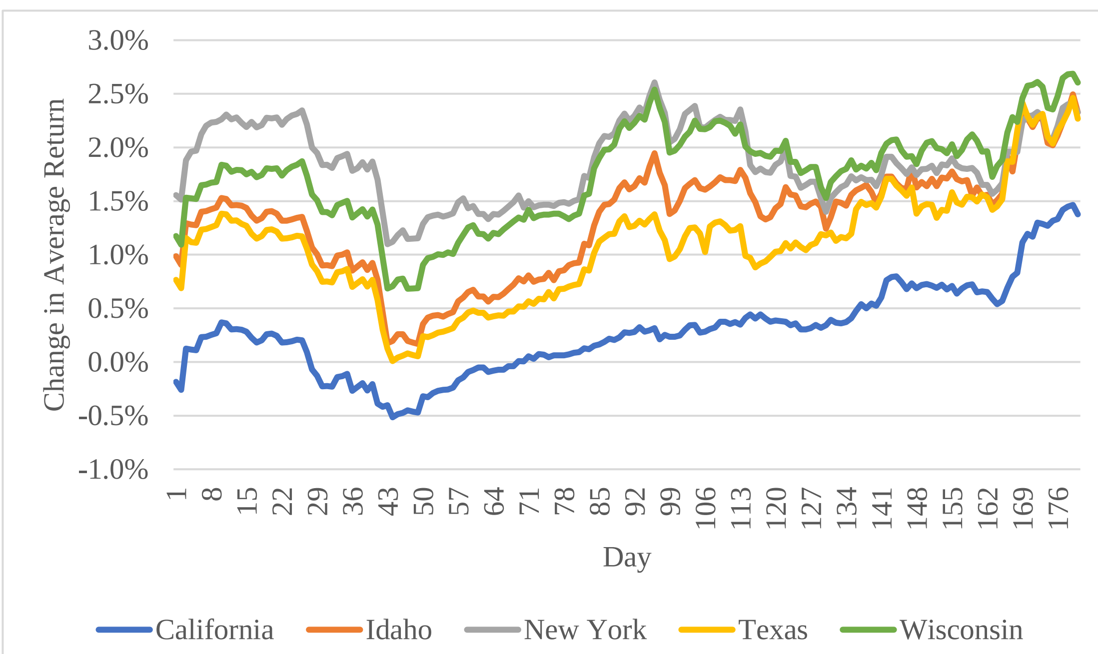

Figure 10: Change in average return (Class price weighting factor = 0.5)

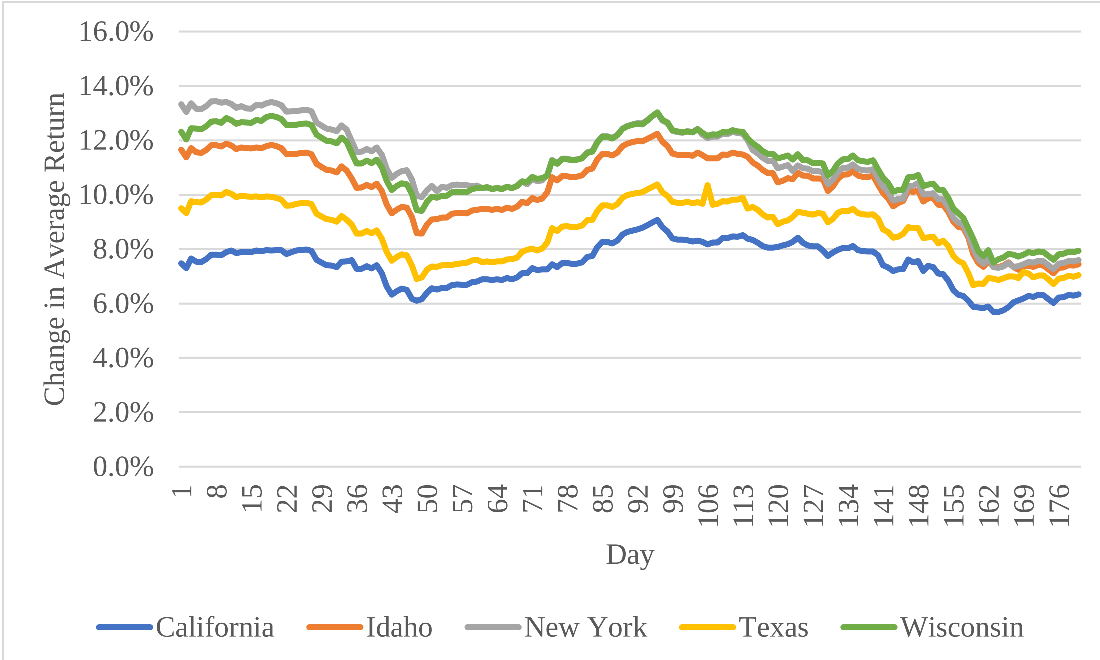

Figure 11: Change in average return (Class price weighting factor = 0)

As is shown in Figure 9, when farmers fully insured on Class III price, Dairy RP did not increase dairy farmers' average revenue in most days during the sales period, which suggests that not buying Dairy RP and accepting actual prices was a good choice for people insuring on Class III price. If farmers purchase Dairy RP, buying on the last day increased average return most (not considering risk reduced) and gave farmers increment lower than 1.5%. Figure 10 shows the curves of the change were generally above 0%. This means insuring 50% each on Class III price and Class IV price can increase the average return for farmers to a limited extent. However, the maximum increase was only 3.5% and occurred during the middle of the sales period. Figure 11 shows the curves of change when fully insuring on Class IV price. In this scenario, the increase was over 14% maximum and about 6% minimum, which is significant.. The best day to buy Dairy RP to increase the average return was generally the first day.

Finally, we combine the analysis of risk and average return to obtain a return-to-risk ratio in order to evaluate the two objectives. Ultimately, we would expect a trade-off between risk reduction and returns. Since farmers want higher average return and lower risk, the date when the highest return-to-risk ratio exist is the best date to buy Dairy RP. From Figures 12, 13, and 14, when class price weighting factor equals to 1, 0.5, and 0, respectively, we find that the best day to buy Dairy RP was the last day, the first day, and around the 40th day, respectively. But these results are based upon a very small sample of 8 quarters during a significant market shock event.

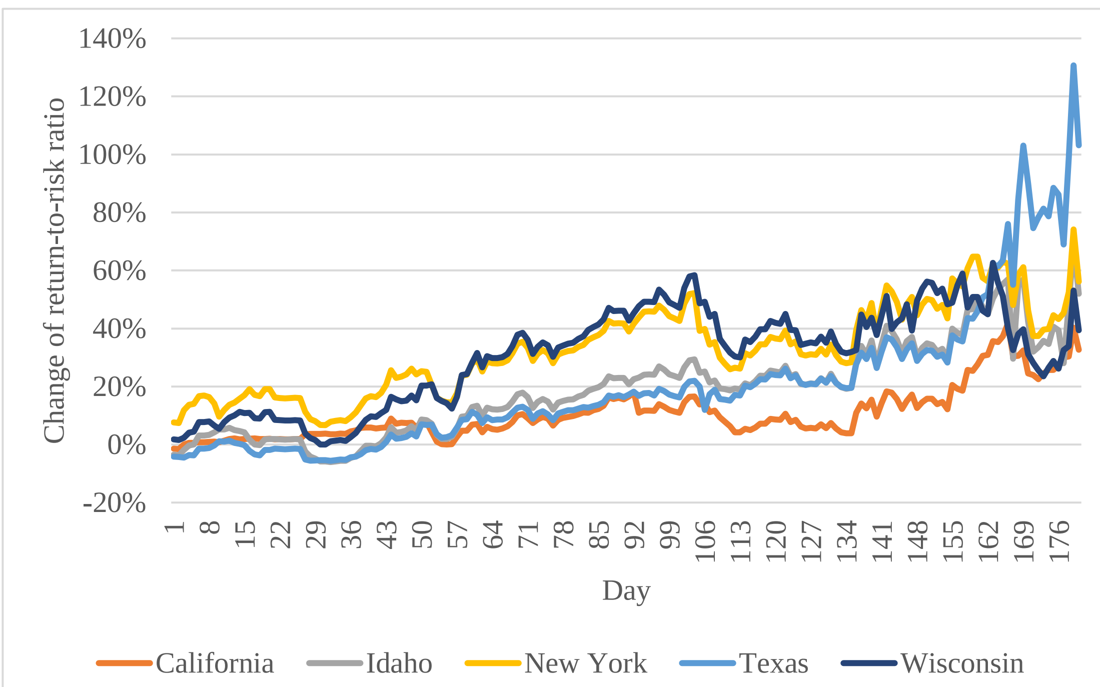

Figure 12: Change of return-to-risk ratio (Class price weighting factor = 1)

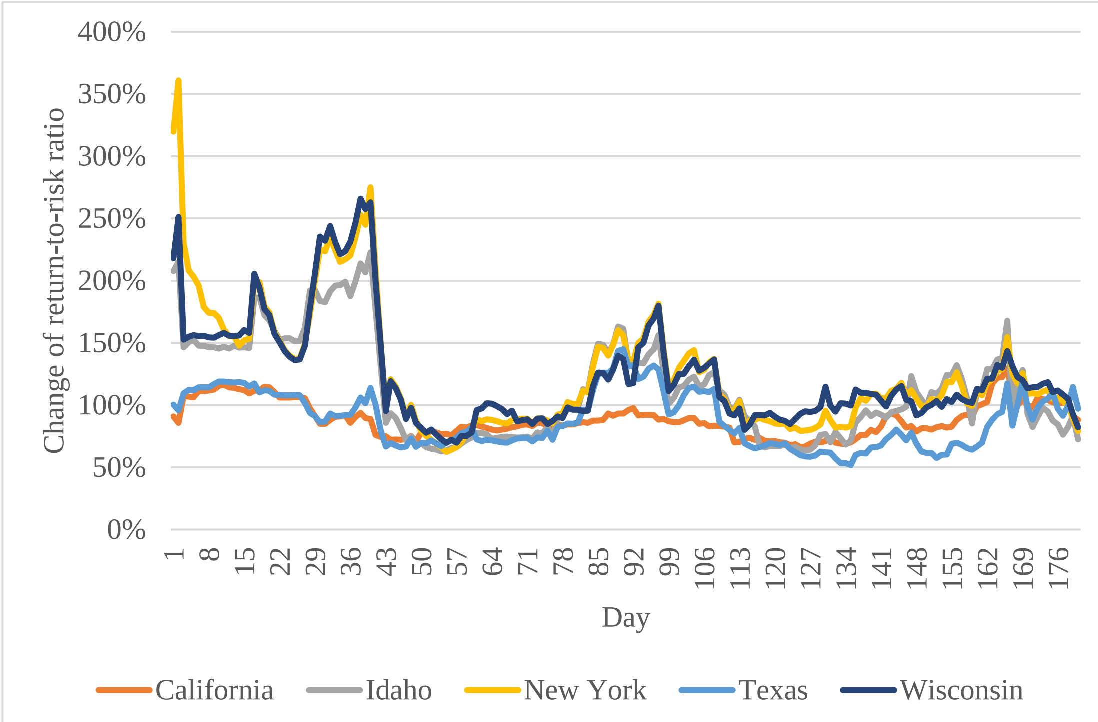

Figure 13: Change of return-to-risk ratio (Class price weighting factor = 0.5)

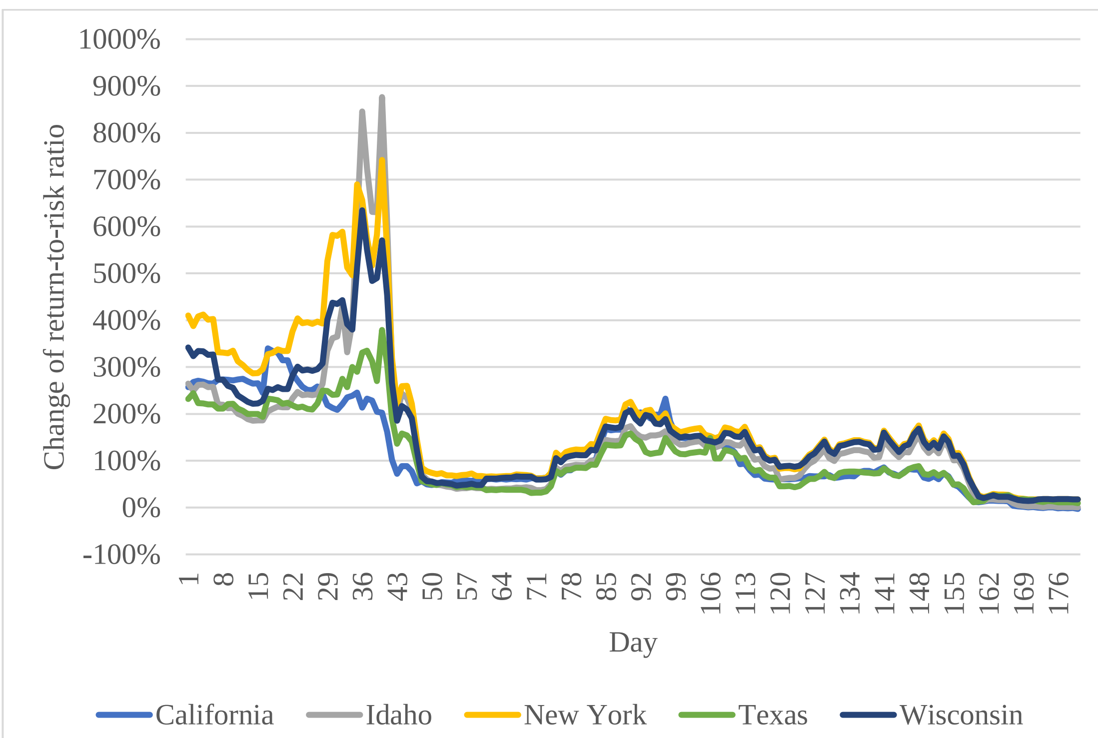

Figure 14: Change of return-to-risk ratio (Class price weighting factor = 0)

Conclusions and Risk Management Implications

From this study, we conclude the following by combining the analysis of risk reduction and change in average return.

For farmers who insure on Class III price, buying Dairy RP on the last day of the sales period can reduce risk and increase average return to the maximum extent. When combing two objectives, the last day is still the best day to buy Dairy RP.

For farmers who insure 50% each on Class III price and Class IV price, buying Dairy RP on the first day can have the best risk reduction effect, and buying in the middle of the sales period can increase average return most. It involves a little trade-off and personal preference. When combing two objectives, the first day is the best day to buy Dairy RP.

For farmers who insure on Class IV price, buying Dairy RP around the 40th day can have the best risk reduction effect, and buying on the first day can increase average return most. It also involves a little trade-off. When combing two objectives, the 40th day is the best day to buy Dairy RP.

REFERENCES

Anderson, D.P., McCorkle, D., Schwart, Jr. R. B., and Jones, R. "Hedging Milk with BFP Futures and Options." AgriLife Extension, Texas A&M System. Internet site: https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/86776/pdf_1028.pdf (Accessed April 21, 2022).

Anderson, J.D., and G. Ibendahl. "Risk Management Tools for Dairy Farmers: Options on Dairy Futures." (2000). Cooperative Extension Service, University of Kentucky. Internet site: http://www2.ca.uky.edu/agcomm/pubs/aec/aec85/aec85.pdf (Accessed April 21, 2022).

Bozic, M. and Wolf, C. "Negative Producer Price Differentials in Federal Milk Marketing Orders: Explanations, Implications, and Policy Options." *Journal of Dairy Science* 105(2022):424–440.

Burdine, K.H., et al. "Livestock Gross Margin–Dairy: An Assessment of Its Effectiveness as A Risk Management Tool and Its Potential to Induce Supply Expansion." *Journal of Agricultural and Applied Economics* 46.2(2014):245–256.

Chavas, J.P., and M.T. Holt. "Acreage Decisions Under Risk: The Case of Corn and Soybeans." *American Journal of Agricultural Economics* 72.3(1990):529–538.

Congressional Research Service. 2017. "Federal Milk Marketing Orders: An Overview." CRS Report R45044. Congressional Research Service.

Newton, J. "What is Dairy Revenue Protection?" 2017. Internet site: https://www.fb.org/market-intel/what-is-dairy-revenue-protection (Accessed April 21, 2022).

Nourse, E.G. "What Lies Ahead for Federal Milk Marketing Orders: Objectives and Means." *Journal of Dairy Science* 45.11(1962):1405–1408.

U.S. Department of Agriculture, Dairy Forward Pricing Program. *Q&A*. 2019. Internet site: https://www.ams.usda.gov/publications/content/dairy-forward-pricing-program-qa (Accessed April 21, 2022).

U.S. Department of Agriculture. *Federal Milk Marketing Order Program: An Overview of the System.* 2019. Internet site: https://www.ams.usda.gov/sites/default/files/media/DairyFMMOBooklet.pdf (Accessed April 21, 2022).

Wolf, C. "Dairy Farmer Use of Price Risk Management Tools." *Journal of Dairy Science* 95.7(2012):4176–4183.

Wolf, C., J.R. Black and J. Hadrich. "Upper Midwest Dairy Farm Revenue Variation and Insurance Implications." *Agricultural Finance Review* 69(Fall 2009):346–358.

Wolf, C. and N. Olynk Widmar. "Dairy Farmer Adoption of Forward-Pricing Methods." *Journal of Agricultural and Applied Economics* 46(November 2014):527–541.

Wolf, C. and Widmar, N. J. O. (2014). "Adoption of Milk and Feed Forward Pricing Methods by Dairy Farmers." *Journal of Agricultural and Applied Economics*, 46(4):527–541.