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James Neyhard, Loren Tauer, and Brent Gloy

Combinations of futures and options contracts on milk and feed were simulated to determine their influence on a representative dairy farm's ability to meet cash flow requirements and reduce the variance of net income. Compared with the reference scenario of selling milk and procuring inputs on a monthly cash basis, the risk management activities did not result in a significant change in either the level or variance of net farm income. The results suggest that on average the current marketing procedure of monthly cash milk pricing and monthly feed purchases (and pricing) produces a strong built-in natural hedge for dairy farmers.

Key Words: dairy risk, futures, hedging, options, simulation

JEL Classifications: D22, Q12, Q13

Market price volatility introduces uncertainty for both the operational and strategic management of dairy farms. A dairy manager must develop a price risk management strategy in the context of a whole farm plan that achieves the overarching strategic goals of the farm (Olson, 2004), yet very little literature is available regarding a whole-farm approach to price risk management for dairy producers; instead, most risk management research has focused on how price risk management strategies impact the variance of prices and revenues. In addition, the full costs of hedging price risk such as margin calls are typically afforded only scant attention. This lack of information regarding the full costs of various risk management strategies and their whole farm impacts forces the dairy manager to make decisions with incomplete information. This article demonstrates the potential impacts of milk and feed price volatility on the financial situation of a dairy farm and determines the potential range of costs and returns for a marketing plan consisting of a set of selective risk management strategies. The marketing plan is built on the production and financial information of the farm as well as the goals of the dairy manager. It is shown how changes in price volatility and the beginning equity of the farm may affect the net benefits of each risk management strategy. The implication is that the risk management strategy selected very much depends on the unique characteristics of the dairy farm.

Monte Carlo simulation techniques are used to simulate prices and determine how various marketing plans would impact a set of ProForma financial statements developed from dairy farm business data. The financial statements include a cash flow budget, income

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statement, and balance sheet. A marketing plan is developed contingent on the financial status and goals of the farm. Hedging triggers based on the milk income margins needed to maintain a positive cash flow determines when the farm will use various risk management tools. Analysis is completed using the @Risk add-in for Excel.

Review of Literature

Although there have been a number of studies that have examined risk management strategies in agriculture, there have been relatively few in the dairy industry. Maynard, Wolf, and Gearhardt (2005) used a risk-minimizing hedge ratio, with respect to futures and cash price variations, to examine how the Dairy Options Pilot Program would impact the price variance faced by farmers. Historical data on futures and options from January 2000 through February 2003 were used in a simulation and demonstrated the potential for a significant reduction in variance from the use of futures and options. Perhaps more importantly, their work presents an overview of the policy drivers and obstacles in creating markets for dairy hedging instruments. They mention the costs of the management time needed to develop marketing strategies and the discipline necessary for implementation. Another work using the basic premises of the risk minimization approach is Manfredo and Richards (2007). They used simulation techniques to examine the effects of monthly hedging on the financial statements of a dairy cooperative. Valuable insights were provided not only in applying various hedging strategies to the dairy industry, but also by presenting results through various measurements, including mean variance and value at risk (VaR), rather than a singular measure of risk reduction.

The method used to evaluate the impact of adopting risk management strategies is an important consideration. Bamba and Maynard (2004) and Zylstra, Kilmer, and Uryasev (2003) used VaR to assess the impact of hedging for dairy farmers. Although these works add to the literature by the application of a novel risk management measurement to agriculture, the measure of value at risk itself is not without faults. Consistent with its relationship to mean variance approaches to risk management, the success of VaR is heavily dependent on the accurate characterization of the underlying behavior and interrelationships between the random variables. In addition, VaR is often criticized for giving a potentially false sense of security, because losses beyond the assumed confidence level could be devastating to the business (Damodaran, 2008).

Another disparity between many hedging and risk management studies and real-world behavior is the separation of risk management activities from the financial structure and goals of the business (Collins, 1997). Collins (1997) acknowledges several studies that attempt to incorporate this linkage, including Turvey and Baker (1989). These models explicitly account for the expected positive relationship between financial leverage and hedge ratios by setting the hedging decision within the greater context of whole farm financial decisions. Others have also gone beyond looking at how hedging influences price variances. In their model of a Virginia dairy farm, Bosch and Johnson (1992) examine how hedging feed costs and the use of crop insurance impact net farm income.

Recent literature has started to examine risk management in a broader light combining financial, business, and strategic considerations as part of the risk management process. Barham et al. (2011) address cotton revenue risk by using a whole-farm simulation of various risk management strategies. In dairy, the Moorepark Dairy System Model takes a whole-farm approach to modeling uncertainty by including milk production, milk prices, and feed prices as stochastic variables (Shalloo et al., 2004). A stochastic budgeting approach has also been used to analyze various farm investment options (Lien, 2003). Others such as the work by Drye and Cropp (2001) moved beyond calendar or time-based hedging decision criteria to more selective approaches, although their results did not show the predicted improvement in cash flow for the farms analyzed. However, several shortcomings were acknowledged in their analysis including the limitations associated with performing a simulation using historical data, basing hedging entry points on historical distributions rather than calculated farm goals, and not

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incorporating the actual costs of hedging. These limitations are addressed in our article.

This article develops marketing triggers based on the current and expected financial situation of the farm. The marketing triggers are designed to meet the farm's cash flow requirements. Thus, the financial situation and operating environment of the farm play an integral role in defining price risk management strategies. These strategies are selective in nature, are based on the business goal of maintaining positive cash flow, and are subject to a desired margin rather than only output or input prices. Costs and cash outflows associated with the simulated risk management strategies, including margin calls and option premiums, are integrated into the analysis. Price movements are simulated from probability distributions rather than using historical prices.

Methods

The modeled goal of the farmer is to achieve returns over feed cost that will meet the cash flow needs during the year. Hedging strategies are evaluated using simulated price paths drawn from fitted price distributions. These price paths and associated costs of implementing a risk management strategy are then used to complete ProForma financial statements for all iterations of the simulation. The cash flow budget, beginning balance sheet, income statement, and ending balance sheet are linked and modeled. These steps, marketing plan development and evaluation of risk management tool performance, are repeated for three different levels of assumed beginning equity for the modeled dairy farm. This allows exploration of whether more highly leveraged operations with greater debt service requirements may have greater incentives to manage the volatility of milk and feed prices.

Previous academic and extension literature regarding risk management on dairies has often focused separately on milk prices, feed prices, or crop yields. In contrast, this work offers an integrated approach toward managing price risk by considering both milk price and purchased feed costs in the context of their impacts on financial statements. To accomplish that objective, income over feed cost is derived using the expected milk production per cow, milk price, ration design, and feed prices to calculate the margin between milk revenues and feed expenses per cow.

We assume that a dairy manager or owner will strive to meet the simple goal of meeting cash flow needs. The desire to meet this goal is a reasonable assumption because it translates to meeting all expense and debt obligations, thus helping to ensure the survival of the business. Using the ProForma financial statements, the required margin per cow can be calculated for this goal. It is assumed that an owner would use the margin as a trigger or guideline, which signals when the use of a risk management tactic should be implemented to protect further erosion in net cash flow.

Milk price and purchased feed commodity prices were modeled as stochastic variables drawn from probability distributions that were fit using historical prices. A basic feed ration is used as a means to convert commodity prices to a purchased feed expense, whereas milk cow numbers and daily milk production per cow are treated as constants to allow the simulated milk and feed prices to be responsible for the variations in empirical results. Feed commodity prices treated as stochastic variables include corn and soybean meal, whereas other commodities in the ration are assigned constant prices. Income over purchased feed cost (IOPFC), or the difference between milk revenues per cow and the combined expense of purchased corn and soybean meal per cow, is calculated based on the assumed ration and financial situation of the dairy farm. Calculated levels of IOPFC required to meet the goal of maintaining positive cash flow are used as triggers.

When simulated prices reach a level that exceeds the IOPFC margin trigger, the use of selected risk management tools is initiated. If the IOPFC remains lower than the necessary margin level before the close-out of the nearby futures contracts, then the farmer remains in a cash position. It is only when the IOPFC is above the desired margin on any given market day that this positive margin is locked in by hedging. The hedge, either with a futures contract or option, is maintained until the expiration

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of the nearby contract used to place the hedge. If the IOPFC margin is not met, the farmer remains in a cash position.

Simulating the daily price path of each commodity allows for the explicit consideration of the potential cost associated with specific risk management strategies. The general action used across all strategies is to fully hedge on a given contract as soon as the associated marketing trigger for that contract is reached. Margins are calculated using a constant basis, added to the daily futures prices of the commodities, as a proxy for the expected cash price.

The cash flow budget used in the model follows the "Dairy Cash Flow" spreadsheet developed by Betz and Robb (2009). Several updates were made to this model including a change in the number and names of the operating receipts and expenses categories. This was done to simplify the cash flow budget by reducing the number of relevant categories and to better match the categories used in the Dairy Farm Business Summary at Cornell University, which serves as the basis for much of the data used in the development of the financial statements.

Several assumptions were used to construct the cash flow budget. Total cash receipts are the sum of milk, dairy calves, cull cows, and other receipts. The total for cash expenditures is determined by the sum of operating expenses, dairy cow purchases, interest expenses, and taxes. If a cash shortfall occurs in any month, the model assumes the cash obligation must be met through the use of a revolving operating loan. Proceeds from milk sales are accrued for 1 month with cash received in the month immediately after the month in which the milk was produced. All purchased feeds arrive at the start of each month, are fed during that month, and paid for at the end of the month. Milk production per cow and the number of cows in milk are assumed to be constant throughout the year. Also, the ration fed to the milking herd is assumed to be constant throughout the year. Feed expenses for heifers were estimated using information available in the literature (Karszes, Wickswat, and Vokey, 2008). The total number of heifers on the farm was estimated based on average proportions between total cows and heifers shown in the Dairy Farm Business Summary (DFBS) (Knoblauch, Putnam, and Karszes, 2008). The number of dry cows was estimated based on an assumption of 85% of the total cow herd being in milk at any time of the year, which implies a 305-day average lactation. For the sake of simplicity, dry cow feed expenses are two times the expenses of feeding heifers. Operating loans are used to cover any cash deficiencies during the year. Annual receipts and expenses were estimated using 2005–2007 summary data for farms over 600 cows from the DFBS (Knoblauch, Putnam, and Karszes, 2006, 2007, 2008). Receipts and expenses per cow were calculated and multiplied by 1,000 to generate the total amounts used in the modeled 1,000 cow dairy.

Cash for capital purchases such as dairy cow replacements was estimated in a similar fashion to other expense categories. Capital purchases for machinery or building improvements were set equal to the estimated depreciation values. This was done in order to maintain depreciable assets from the beginning to the end of the year. Gross family living withdrawals were taken from the DFBS. The operation is assumed to be a sole proprietorship with a combined state and federal individual income tax rate of 35%. Income and Social Security taxes were estimated by calculating the net farm income and multiplying by the assumed total tax rate. With respect to planned debt payments, monthly principal and interest amounts were taken directly from amortization tables for both intermediate and long-term liabilities.

After completion of the income statement, the ending balance sheet is constructed to compute ending equity. The ending cash balance and accounts receivable values are calculated from the cash flow budget. Finally, these ProForma financial statements are used to determine the marketing triggers that in turn help to determine actions to manage market price risk.

Development of the Price Generator for Stochastic Prices

Much past research has examined price patterns over specific years to determine how a farmer may have best reduced income variability or increased returns (Tomek, 1997;

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Wisner, Blue, and Baldwin, 1998; Zulauf and Irwin, 1998; Zulauf et al., 2001). Although these are actual price patterns, they are limited to only a few price scenarios that might have occurred in these years. As an alternative, a better approach may be to develop a data generator function and use that generator to create thousands of years of price patterns. That is the approach used in this study. Futures prices for milk, corn, and soybeans were generated on a daily basis for each commodity and contract. The approach used the log normal model of prices as is commonly used in the financial literature. This structure is as follows:

$$S_t = S_0 \exp(\mu - 0.5\,\sigma^2)t + \sigma\sqrt{t}Z$$

where:

S_t = Current price

S_0 = Previous price

exp = Exponential operator

μ = Instantaneous return

σ = Annual volatility

t = Timeframe based on total trading days (i.e., 1/total trading days is 1 day)

Z = Normal (0,1) random variable

The log normal function is simulated with the @Risk add-in for Excel to create price series that follow a random walk (Winston, 2001). These price series provide a useful method to evaluate the effectiveness of various risk management tools and strategies. Price information from 2003–2008 was used to estimate price distributions and volatility parameters for class III milk, corn, and soybean meal futures contracts. Using the BestFit tool within the @Risk add-in for Excel, the aggregated daily closing prices for each contract month were used to estimate distribution parameters. No correlations assumptions were made either between or among commodity contracts. The simulation model then randomly picks a starting price from the estimated distribution as the starting price for each price series. Thus, all iterations of the simulation begin with a random starting price. Distributions for the starting prices of each commodity contract were estimated using daily closing prices for each commodity. Distribution fits were ranked using a χ^2 goodness-of-fit test. The distribution with the closest fit to the aggregated data was then used to generate the initial starting price.

When the distributions were simulated, the expected value of the instantaneous rate of return was assumed to be zero to avoid including an average trend in the price series. The annualized volatility was estimated by calculating the standard deviation, across the entire life of each commodity contract, of the log normal daily returns. This figure was then multiplied by the square root of the number of trading days, thus yielding the annualized volatility (Hull, 2003).

The price series generated using the estimated parameters were filtered so that daily price changes did not exceed the limits set by the commodity exchanges. Specifically, the filter eliminated price changes in the raw series greater than the limit moves by substituting the limit move value; otherwise, the generated price change was used. Although the major commodity exchanges adjust the limit moves at different points during the life of the contract, a constant limit was deemed a suitable assumption for the purposes of this work.

The setting of this model is of a dairy manager who develops marketing triggers at the beginning of the year based on the financial structure and goals of the dairy farm business and uses these triggers to make risk management decisions for the duration of the coming year. To avoid any speculative position in managing price risk, the owner is assumed to use the forward nearby futures or option contracts in managing feed and milk prices and each position is closed out on the same day that transactions are made on the cash market. However, there does remain a slight speculative aspect to the corn and soybean meal hedging because the specified contract sizes are greater than the feed requirements on the farm.

Because the financial structure of the farming operation will alter the critical cash flow levels of the operation, the analysis examines how three financial structures would impact the usefulness of risk management strategies. These

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scenarios are referred to as low, average, and high debt, which use 30%, 65%, and 80% debt, respectively.

The procedure for calculating the margin required to maintain cash flow is summarized in Table 1. All operating expenses except for corn and soybean meal are converted into cash requirements per cow per day. For the high debt farm, the cash flow requirement is $13.87 per cow per day. If milk receipts per cow per day minus the feed costs per cow per day are at or above this level on any given day, then a hedging tactic is put into play to secure the margin.

Modeling Futures Contract Hedging

The first alternative to cash marketing is hedging through the use of futures contracts. In the case of hedging using futures contracts, the model calculates both deposits and margin calls occurring each month. Calculating these costs is a critical feature because the cash flows necessary to maintain positions may not be evenly balanced across the contract months. Contracts across all months of the year may be entered into during the beginning of the year, creating large maintenance costs during the beginning of the year, whereas the potential benefits would be spread evenly through the business year. The ending account balance for each contract, less brokerage fees, which becomes a source of cash in the month which the position is closed, is calculated. Values used for initial and maintenance margin requirements are based on information available from the CME Group web site (www.cmegroup.com). An assumed transaction cost of $70 per round turn of each contract was made for the sake of simplicity.

Modeling Hedging through Options on Futures Contracts

The second type of risk management tool considered is an option on a futures contract. Options are available on commodity futures contracts at varying strike prices ranging from those "in the money" to those "out of the money." For example, in the money, put (call) options would have a strike price in excess of (below) the current futures price. This presents decision-makers with a wide range of possible choices regarding which strike prices to purchase. For the purposes of this work, the use of at the money options was simulated. This was done to allow comparison of the relative costs of futures contracts vs. options because each strategy will be based on the same beginning hedged price.

Option premiums were simulated within the same worksheet as futures contracts. For the sake of simplicity, options were specified as European (exercised only at expiration) to determine option prices. When a market signal triggers the use of a futures contract, the model simultaneously uses the entry price of the futures contract to calculate the beginning premium of an at the money option. Thus, the use of futures and options can be compared by the

Table 1. Examples of the Hedging Strategy Trigger Calculations for Low, Average, and High Debt Farm Scenarios

Calculation Fields	Low Debt	Average Debt	High Debt
Total operating expenses (less corn and soybean meal expenses)	$3,555,496	$3,555,496	$3,555,496
+ Income taxes	$209,418	$209,418	$209,418
+ Family living and other draws	$84,113	$84,113	$84,113
+ Scheduled principal and interest payments	$184,113	$415,830	$908,224
+ Cash required for capital replacement	$306,745	$306,745	$306,745
"Meet cash flow demands—income over purchased feed cost"	$4,339,884	$4,571,601	$5,063,995
"Meet cash flow demands—income over purchased feed cost" per cow	$4,340	$4,572	$5,064
Per cow/day	$11.89	$12.52	$13.87

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user based on the same price series. In addition to the price series, the duration, or the life of the option, based on the difference between the final trading day associated with the milk sale or feed purchase and the day in which the option was bought is recorded. The volatility measure for each option premium is the same as that used in the price generator detailed earlier. The risk free rate is assumed to be 5%. The option premiums are calculated using Black's option pricing formula (Hull, 2003).

Option premiums typically do not change in value at the same rate and magnitude as the underlying futures contract. The measure of this relationship is known as the delta value. The delta value in this article was assumed to be 0.5; thus, option premiums are assumed to change at half the rate of the price of futures contracts. Therefore, a producer using options to gain the same hedging efficiency as futures contracts would need to buy twice as many options as futures contracts (Pennings and Meulenberg, 1997).

Simulation and Evaluation of Risk Management Tools

Cash marketing, hedging with futures contracts and options on futures contracts, and combinations of these tools were evaluated against price series generated through Monte Carlo simulation techniques. Table 2 summarizes the various risk management combinations. Each possible combination of milk and feed risk management tools (cash, hedging with futures, and options) was evaluated in every simulation. Nine simulations were run with three marketing strategy environments and three initial debt levels. Each simulation included 5,000 iterations.

Table 3 illustrates the definition for each of the simulations. The marketing strategy environments represent the simulated market situation facing the decision-maker and include a baseline scenario with parameters estimated based on historical data, an increased volatility environment, and finally a scenario in which only 50% of milk production is hedged. Three different initial debt levels were chosen to see whether the initial level of debt influenced the attractiveness of using a cash flow trigger to initiate hedging. The basic hypothesis is that farms with more leverage would see a greater benefit from using the cash flow hedging trigger.

Results

Low Debt Farm

The baseline simulation results for the low debt farm with a debt to asset ratio of 30% are shown in the top third panel of Table 4. The first term of the notation on the vertical axis indicates how milk was priced and the second term indicates how the feed ingredients of corn and soybean meal were priced. All of the risk management options have very similar average net returns. Use of hedging strategies generally reduced variance of income with a corresponding reduction in average income, but the impact is very minor. Using futures on milk, corn, and soybean meal reduces the variance of income compared with cash positions by only 5.5% and at the cost of lowering income by 3.4%. This is primarily because dairy production may already contain a natural hedge. Milk is priced monthly in the cash market and our modeling assumes corn and soybean meal are priced and purchased monthly as well, a common practice in dairy operations. The only strategy that did not reduce the variance in net farm income was the use of options on feed purchases. The increased variance in this scenario is likely the

Table 2. Marketing Strategies and Risk Management Tool Combinations[a]

	Milk Marketing Risk Management Tools		
Corn and Soybean Meal Purchasing Risk Management Tools	"Cash/Cash"	"Futures/Cash"	"Options/Cash"
	"Cash/Futures"	"Futures/Futures"	"Options/Futures"
	"Cash/Options"	"Futures/Options"	"Options/Options"

[a] Strategy types indicated as X/X, the first is how milk is sold, the second is how corn and soybean are purchased.

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Table 3. Simulation Definitions

Simulation	Farm	Equity	Volatility Parameters	Percent Milk Production Hedged
1	Low debt	80%	Baseline	100%
2	Low debt	80%	Doubled	100%
3	Low debt	80%	Baseline	50%
4	Average debt	65%	Baseline	100%
5	Average debt	65%	Doubled	100%
6	Average debt	65%	Baseline	50%
7	High debt	30%	Baseline	100%
8	High debt	30%	Doubled	100%
9	High debt	30%	Baseline	50%

result of the higher upside associated with this strategy.

It is unusual to find the use of options increase average income, but that is the case here. Options mitigate downside risk, which can periodically increase returns, although market efficiency should allow that to rarely happen and not on average. In this case, the increase in

Table 4. Low Debt Farm: Net Farm Income Summary

Marketing Strategy[a]	Average	Standard Deviation	5%[b]	95%
		Results with Baseline Volatility Parameters		
Cash/Cash	$348,836	$131,674	$150,362	$577,534
Cash/Futures	$340,449	$128,532	$146,060	$562,139
Cash/Options	$349,148	$131,985	$148,721	$577,926
Futures/Futures	$336,997	$124,304	$147,169	$552,455
Futures/Cash	$338,203	$124,726	$147,657	$553,868
Futures/Options	$338,222	$124,881	$146,961	$554,714
Options/Options	$349,523	$131,010	$151,542	$579,229
Options/Cash	$349,423	$130,829	$151,815	$574,927
Options/Futures	$340,585	$127,360	$147,291	$561,999
		Results with Doubled Volatility Parameters		
Cash/Cash	$348,764	$178,470	$72,690	$663,226
Cash/Futures	$331,572	$174,141	$57,777	$632,236
Cash/Options	$350,829	$179,129	$71,183	$667,622
Futures/Futures	$314,029	$152,336	$70,141	$563,835
Futures/Cash	$317,191	$154,042	$70,109	$570,833
Futures/Options	$317,894	$154.022	$70,693	$568,225
Options/Options	$345,575	$171,280	$78,594	$638,300
Options/Cash	$344,934	$171,298	$79,332	$634,458
Options/Futures	$325,904	$165,490	$70,574	$607,326
		Results with Baseline Volatility and 50% Hedging		
Cash/Cash	$348,838	$130,357	$152,414	$575,368
Cash/Futures	$340,461	$127,161	$148,659	$559,829
Cash/Options	$349,178	$130,469	$153,281	$575,832
Futures/Futures	$342,370	$124,797	$150,972	$554,205
Futures/Cash	$343,253	$125,126	$152,156	$555,377
Futures/Options	$343,476	$125,206	$151,491	$556,016
Options/Options	$348,588	$128,002	$152,156	$566,868
Options/Cash	$348,332	$127,870	$152,977	$567,143
Options/Futures	$339,774	$124,539	$148,343	$552,004

[a] Strategy types indicated as X/X, the first is how milk is sold, the second is how corn and soybean are purchased.
[b] The 5% and 95% columns indicate the net farm income associated with the 5% and 95% probability levels in the cumulative distribution of net farm income.

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average net return is very small and may simply reflect small errors in assumed coefficients and computations in our model. For instance, we assumed an option hedge delta of 0.5, which was held static at that value and not dynamically adjusted over the life of a hedge as the option value changed. An additional way of differentiating the success of each marketing strategy is to analyze the range in simulated net farm income. Table 4 shows the highest 95% and lowest 5% income, and these ranges correspond to the average and variance measures, as would be expected with 5,000 performed simulations.

Many producers and their bankers are unwilling to engage in hedging strategies because of the cost and potential cash flow demands (margin calls) of implementing these strategies even if these strategies reduce risk. For futures contracts, both account deposits and margin calls are included in calculating total costs, whereas costs for options are considered to be the premiums paid. The costs of implementing the various risk management strategies in the baseline simulation are shown in the first two columns of Table 5. The strategies involving the use of futures contracts generally had much higher risk management implementation costs as a result of the margin calls that were required by the strategies. As such, the risk management costs should be thought of as the costs associated with implementing the strategies rather than a total cost. The net impact of these strategies on net farm income of these strategies was much smaller (Table 4) because the net farm income results include the positive income effects associated with hedging as well. Hedging occurred in 4,832 iterations of the 5,000 total iterations.

The middle panel of Table 4 shows the results for the low debt farm when the volatility parameter in the price generating formula is doubled. This allows for the effects of increased volatility on the relative success of the risk management strategies to be isolated and observed. With doubling of volatility, the benefits of hedging strategies are more apparent. The standard deviation of net income is reduced except when the farmer remains in the cash milk market and uses options in the feed markets. The use of futures contracts again provided the greatest reduction in the variance of net farm income similar to the results of the baseline simulation. The variance reduction effect, as measured by the differences in the coefficient of variation among the strategies, was nearly two to three times greater than the variance reduction provided by the use of futures contracts in the baseline simulation. Hedging of at least one commodity occurred in 4,990 of the 5,000 iterations for this simulation. Doubling the volatility significantly increased the average total risk management costs for all marketing strategies as shown in the third and fourth columns of Table 5. The "Cash/Options" combination on average has the lowest total costs as it did in the initial simulation for the low debt farm. Once again, the futures based strategies carry the highest average cost.

The third and final simulation for the low debt farm is shown in the bottom third of Table 4.

Table 5. Low Debt Farm: Marketing Strategy Total Risk Management Costs

Marketing Strategy[a]	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
	Baseline Volatility		Doubled Volatility		Baseline Volatility and 50% Hedging	
Cash/Futures	$38,364	$25,794	$81,354	$47,766	$38,426	$25,480
Cash/Options	$12,760	$6,900	$37,052	$14,678	$12,812	$6,809
Futures/Futures	$128,757	$78,136	$313,702	$161,819	$78,110	$45,272
Futures/Cash	$102,223	$66,159	$256,369	$144,731	$51,497	$33,211
Futures/Options	$114,983	$71,682	$293,421	$155,113	$64,309	$38,682
Options/Options	$71,104	$38,209	$208,357	$81,269	$42,029	$22,038
Options/Cash	$58,344	$31,637	$171,305	$67,383	$29,217	$15,522
Options/Futures	$96,708	$54,191	$252,659	$106,398	$67,643	$38,811

[a] Strategy types indicated as X/X, the first is how milk is sold, the second is how corn and soybean are purchased.

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This simulation uses the baseline parameters but only allows the model to hedge up to 50% of the annual milk production and the feed inputs required to produce that milk. It is equivalent to using a partial cash marketing strategy in conjunction with all other risk management strategies, thus leaving open the possibility of a wider range in net farm income. It tests whether comparable ranges of net farm income and reductions in net farm income variance can be achieved with lower amounts of capital invested in risk management tools. Net farm income was reduced slightly in absolute dollar amounts with a reduction in the coefficient of variation. Comparing the performance of the reduced hedge ratio strategy to the baseline shows both advantages and disadvantages for reducing the hedge ratio. In favor of reducing the hedge ratio are the facts that on average total risk management costs will decrease (fifth and sixth columns of Table 5) with a lower reduction in net farm income from the higher full cash position than from full hedging. These results are the result of the cash market exposure maintained across all marketing strategies with less than full hedging. Thus, when market prices move in an unfavorable way with regard to a hedge, and vice versa, there still remains a cash market exposure to balance the negative or positive effects. This marketing plan still leaves open the upside potential of the cash marketing strategy but with the drawback of less downside protection.

Average Debt Farm

Identical simulations that were run for the low debt farm were also run for the average debt farm. Increased debt payments and marketing triggers represent the only fundamental difference in the structure of the model between the low debt farm and the average debt farm. As a result of the increased debt payments, calculated marketing trigger levels increased in value. As can be seen from the top panel of Table 6, the cash marketing strategy provided the highest average net farm income levels in the baseline simulation for the average debt farm. The total risk management costs across all marketing tool combinations do not differ markedly on average from the low debt farm baseline simulation and are not shown. In addition, despite the increase in value of the marketing trigger to $12.52, the number of iterations in which hedging occurred, at 4,855 iterations, also did not change tremendously.

The results for the doubled volatility simulation for the average debt farm are shown in the middle panel of Table 6. The strategies using futures contracts on price milk succeeded in reducing the coefficient of variation by 1–2%. Interestingly, the "Cash/Futures" strategy actually increased the coefficient of variation above the cash marketing strategy; however, this is likely the result of the higher upside results of the strategy.

The simulation results using the baseline parameters and decreasing the maximum amount of milk hedged to 50% of production are shown in the bottom panel of Table 6. The cash marketing strategy resulted in the highest average net farm income with the "Cash/Options" and "Options/Cash" strategies close behind. Once again the use of futures contracts successfully reduced the variance in net farm income. Variance reductions resulting from a 50% hedge ratio on milk were comparable to those resulting from a full hedge. The cash marketing strategy provided the greatest upside potential in net farm income.

High Debt Farm

The last set of simulation results is for the high debt farm. All parameters were held constant across these debt levels with the exception of the marketing triggers, which as a result of the additional debt obligations of the high debt farm increased to $13.87. As shown in the top panel of Table 7, the cash marketing strategy again presented the highest average net farm income. The "Cash/Options" strategy allowed for the greatest upside potential, whereas the "Options" strategy provided the most downside protection. Those strategies using the use of futures contracts in pricing milk reduced the coefficient of variation by approximately 1%. Hedging occurred in 4,835 of the 5,000 iterations of this simulation.

The first two columns of Table 8 summarize the total risk management costs for the baseline

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Table 6. Average Debt Farm: Net Farm Income Summary

Marketing Strategy[a]	Average	Standard Deviation	5%[b]	95%
		Results with Baseline Volatility Parameters		
Cash/Cash	$299,742	$135,104	$95,899	$530,040
Cash/Futures	$290,685	$131,799	$91,595	$513,846
Cash/Options	$299,678	$135,278	$96,258	$528,901
Futures/Futures	$285,493	$125,876	$97,428	$499,578
Futures/Cash	$287,138	$126,511	$97,562	$501,863
Futures/Options	$286,847	$126,502	$97,562	$502,852
Options/Options	$297,987	$132,487	$101,195	$522,425
Options/Cash	$298,292	$132,471	$100,092	$521,146
Options/Futures	$288,815	$128,748	$97,340	$504,614
		Results with Doubled Volatility Parameters		
Cash/Cash	$299,781	$176,340	$38,757	$602,828
Cash/Futures	$281,423	$172,301	$20,652	$579,007
Cash/Options	$301,211	$176,741	$37,642	$601,050
Futures/Futures	$263,859	$150,763	$30,555	$509,529
Futures/Cash	$266,705	$152,370	$30,723	$517,475
Futures/Options	$267,511	$152,263	$33,687	$518,521
Options/Options	$294,555	$168,115	$37,041	$575,039
Options/Cash	$293,922	$168,229	$39,367	$569,193
Options/Futures	$274,757	$162,895	$25,560	$543,286
		Results with Baseline Volatility and 50% Hedging		
Cash/Cash	$299,936	$130,520	$103,849	$527,145
Cash/Futures	$290,759	$127,198	$100,096	$507,543
Cash/Options	$299,847	$130,704	$105,898	$526,041
Futures/Futures	$291,822	$124,788	$102,414	$506,399
Futures/Cash	$293,465	$125,339	$103,123	$507,541
Futures/Options	$293,203	$125,355	$103,646	$508,190
Options/Options	$298,468	$128,627	$104,555	$520,111
Options/Cash	$298,700	$128,576	$104,810	$519,688
Options/Futures	$289,261	$124,940	$101,367	$502,617

[a] Strategy types indicated as X/X, the first is how milk is sold, the second is how corn and soybean are purchased.

[b] The 5% and 95% columns indicate the net farm income associated with the 5% and 95% probability levels in the cumulative distribution of net farm income.

simulation of the high debt farm. On average the total risk management costs for the high debt farm are comparable to those for the low and average debt farm. In addition, the number of iterations in which hedging occurred is also comparable despite the marketing trigger increasing in value. In general, those marketing tool combinations using futures contracts have higher costs on average and have a higher positive skew. Based on the relative returns, the "Futures"-based strategy provided the least negative return when net farm income was below the cash marketing strategy level, whereas the "Options/Cash"-based strategy provided the highest return when net farm income was above the cash marketing strategy level. The "Cash/Options" strategy provided the highest net farm income on average for double volatility on the high debt farm. Interestingly, the "Options" and "Options/Cash" strategies provided the greatest reductions in the coefficient of variation. Similar to the results for the low and average debt farms, the total risk management costs for the high debt farm more than doubled when the volatility parameter was doubled.

When up to 50% of the milk production was allowed to be hedged on the high debt farm, the cash marketing strategy produced the highest average net farm income. All strategies with the exception of the "Cash/Futures" and "Options/

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Table 7. High Debt Farm: Net Farm Income Summary

Marketing Strategy[a]	Average	Standard Deviation	5%[b]	95%
		Results with Baseline Volatility Parameters		
Cash/Cash	$192,418	$134,058	−$12,126	$421,234
Cash/Futures	$183,014	$130,312	−$13,864	$403,748
Cash/Options	$192,244	$133,988	−$10,942	$422,063
Futures/Futures	$177,328	$123,566	−$11,956	$387,920
Futures/Cash	$178,783	$124,211	−$10,916	$391,448
Futures/Options	$178,560	$124,151	−$11,323	$390,719
Options/Options	$189,822	$130,748	−$8,387	$418,614
Options/Cash	$190,064	$130,812	−$7,308	$416,897
Options/Futures	$180,602	$127,071	−$12,105	$400,280
		Results with Doubled Volatility Parameters		
Cash/Cash	$192,114	$177,917	−$82,769	$499,612
Cash/Futures	$173,135	$173,042	−$97,382	$463,880
Cash/Options	$193,221	$177,980	−$80,081	$499,587
Futures/Futures	$155,707	$149,926	−$79,366	$404,000
Futures/Cash	$158,623	$151,366	−$79,149	$407,108
Futures/Options	$159,664	$151,419	−$76,503	$410,342
Options/Options	$186,463	$167,079	−$70,778	$473,966
Options/Cash	$185,435	$166,804	−$72,126	$471,024
Options/Futures	$166,465	$161,672	−$84,995	$439,402
		Results with Baseline Volatility and 50% Hedging		
Cash/Cash	$192,085	$133,594	−$7,179	$418,804
Cash/Futures	$182,776	$129,896	−$10,186	$406,482
Cash/Options	$191,758	$133,457	−$7,865	$418,131
Futures/Futures	$184,251	$126,777	−$9,074	$397,467
Futures/Cash	$185,832	$127,606	−$8,289	$402,310
Futures/Options	$185,477	$127,449	−$9,711	$398,760
Options/Options	$191,130	$130,876	−$8,155	$412,869
Options/Cash	$191,487	$131,018	−$6,996	$415,654
Options/Futures	$182,155	$127,197	−$9,685	$398,021

[a] Strategy types indicated as X/X, the first is how milk is sold, the second is how corn and soybean are purchased.
[b] The 5% and 95% columns indicate the net farm income associated with the 5% and 95% probability levels in the cumulative distribution of net farm income.

Futures" strategies succeeded in reducing the variability of net farm income as measured by the coefficient of variation. Of note is the fact that the downside risk measured by the net income associated with the 5% level on the cumulative distribution of the cash marketing strategy was not improved by the hedging strategies in this simulation. This alludes to the need of more highly leveraged operations to increase the hedge ratios in their market plan to gain the benefit of downside protection. Hedging only 50% of the milk production provides additional exposure to the variance in the cash market, which pushes the average net farm income just slightly ahead of the average net farm income in the full hedging results of the baseline simulation.

Discussion

In general the results are in line with the expectation that hedging reduces net farm income and reduces its variation. Across debt levels, net farm income decreased as debt level increased; however, the absolute level of variance in net farm income was relatively comparable among all simulations. In light of the decreasing average net farm income, the coefficient of variation increased as debt levels increased. Use of futures and options decreased the standard

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Table 8. High Debt Farm: Marketing Strategy Total Risk Management Costs

Marketing Strategy[a]	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
	Baseline Volatility		Doubled Volatility		Baseline Volatility and 50% Hedging	
Cash/Futures	$38,564	$25,716	$81,409	$47,223	$38,383	$25,783
Cash/Options	$12,744	$6,882	$36,869	$14,489	$12,825	$7,018
Futures/Futures	$128,690	$78,968	$310,905	$158,942	$77,950	$45,895
Futures/Cash	$102,171	$67,091	$253,782	$142,226	$51,264	$33,449
Futures/Options	$114,915	$72,572	$290,651	$152,452	$64,089	$39,168
Options/Options	$70,910	$37,859	$207,459	$80,360	$42,097	$22,587
Options/Cash	$58,166	$31,322	$170,591	$66,671	$29,272	$15,864
Options/Futures	$96,730	$53,967	$251,999	$105,228	$67,656	$39,494

[a] Strategy types indicated as X/X, the first is how milk is sold, the second is how corn and soybean are purchased.

deviation of net farm income by slightly increasing amounts as debt levels grew, which would represent greater percentages of net farm income for higher debt farm. Thus, it could be concluded that risk management tools protect a greater proportion of net farm income as debt level rises.

Although borrowings against the operating line increased across debt levels, this likely was attributable mainly to the associated increase in total debt obligations because any low price environment would push a higher debt farm with lower equity to borrow sooner than a lower debt farm. Total risk management costs remained relatively stable across debt levels among similar simulations. These results lead to the conclusion that higher debt farms may have a greater incentive to hedge. Based on the relatively stable costs of risk management, the variance reductions provided to higher debt farms provide a higher return because each dollar in variance reduction represents a greater proportion of expected net farm income.

Some differences do exist between the strategy results. The costs between each of the general groups of marketing tools of cash, futures, and options differ considerably. One way to look at these costs is to think of them as substitute risks. In this sense, the decision-maker is exchanging risk in the cash marketplace with the risk of potential costs associated with the various risk management tools. One could differentiate between the use of futures and options according to the nature of their costs. Futures costs are not fixed and may vary dramatically. Alternatively, the use of options incurs a fixed cost, similar to an insurance policy.

In addition, a decision-maker analyzing these results should keep in mind that absolute net farm income levels affect the financial wellbeing of the operation, whereas estimated reduction in the variance of net farm income is not directly realized. In other words, variance in net farm income was decreased using strategies used in this work but was based on several 5,000 iteration simulations. In reality, however, a decision-maker works with a much smaller sample space assuming each of the iterations in a simulation is comparable to a single marketing year. Thus, although in the long run variance is reduced, it is possible that in the short term the results of a risk management strategy will be minor reductions in variance at a high cost.

Conclusions

This article analyzed the use of market risk management strategies and tools for dairy farms through the use of simulation techniques. ProForma financial statements were constructed as a medium for this analysis. Simulations were designed to mimic the price environment faced by dairy managers. The article provided a unique extension to the literature by explicitly considering the full distributions of the costs and benefits of hedging. In addition, this work used a selective hedging strategy based on the financial situation of the dairy farm.

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Results indicate that variance in net farm income can be reduced through the use of risk management tools but at the cost of lower expected net income. Strategies using cash marketing to price milk production had the highest variance in net farm income but generally the highest expected income. The use of futures contracts provides the greatest reduction in net farm income variance but is accompanied by the highest total marketing costs on average. Although options-based strategies do not reduce net farm income variance as greatly as futures contracts, they do provide comparable minimum net farm income protection while at the same allowing for higher upside potential of net farm income than is found in the results for strategies based on futures contracts. The use of options in averting market risk has lower total marketing costs, which are also not as variable as the costs associated with futures contracts. However, strategies using options typically had lower returns. In general, hedging only 50% of the milk production resulted in higher returns on investment because average costs decreased from the levels associated with full hedging by a greater amount than did the average reduction in net farm income standard deviation through the use of risk management tools. In considering the variance reduction of the various hedging strategies, it must be recognized that milk is priced monthly and feed is purchased monthly so that the cash positions in both milk and feed replicate a natural hedge for risk reduction. Obviously, the strategy selected by a farmer depends on risk preference and other considerations. The implementation of all except the default of cash sales imposes a learning cost, which was not considered, and some farmers may find it more beneficial to use their time in other aspects of dairy management with higher perceived returns.

Although this research presents a comprehensive approach to modeling the performance of various market risk management tools, it does allow for additional research opportunities. Although the action of the marketing strategy modeled, which is to hedge when the desired income over purchased feed cost becomes sufficient to meet cash flow needs, represents a novel approach to modeling the strategic choices of a decision-maker, future work would complement the results of this work by simultaneously evaluating other marketing actions such as those based on time or the position of current prices relative to historic measures. Including these types of marketing actions would allow for comparisons against those strategies previously examined in the literature regarding risk management on dairy farms.

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