Multi-Commodity Hedging in the Live Cattle Futures Market

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Abstract

The benefits of price risk management using commodity market futures and options contracts have been studied extensively. However, recent increases in commodity market futures volume and volatility have caused some agricultural producers to conclude that hedging has become less effective. We investigate single- and multi-commodity hedging over time using second-order lower partial moments (LPM_2) minimizing hedge ratios and minimum-variance (MV)-based hedging strategies. We evaluate the performance of these strategies using a Monte Carlo procedure and rolling window approach. We find that the multi-commodity hedge ratios of corn are quite different from the single-commodity hedge ratios under both MV and LPM_2 criteria, because the multi-commodity hedge ratios of corn are dominated by the cross-dependence between live cattle and corn, which is not involved in the single-commodity hedging procedure. In spite of the increased futures volume and volatility, we also find that the hedging strategies perform better than non-hedging strategy, especially the multi-commodity hedging strategy, across all criteria. Hedging effectiveness is essentially unchanged over the last fifteen years, and agricultural producers concern over futures market volume and volatility is misplaced.

INTRODUCTION

In 2016, the National Cattlemen's Beef Association (NCBA) wrote an open letter claiming that the increased trading volume and volatility of live cattle futures contracts have turned futures into a liability rather than a benefit. They claimed that high frequent trades caused the increased volatility, which made their hedging more expensive and less effective (Ellis and Greiman 2016). However, textbook hedging models claim show trading in the future market could help feedlot operator reduce the risk of cattle price uncertainty in the future even during periods of increased volatility. Though the hedging literature does not appear to validate the NCBA's concerns, we investigate whether empirical support exists for concerns over the financialization of cattle and hedging effectiveness.

The existing literature on live cattle hedging focuses on single-commodity hedging using minimum variance. In recent years, the downside risk measures, such as lower partial moment, are more commonly used as the hedging criteria, because it requires fewer assumptions and more suitable to the utility of the hedger (who is concerned more about loss than gain) better than minimum variance criteria (Power and Vedenov 2010; Mattos, Garcia and Nelson 2008). Moreover, cattlemen face risk from both the feedstuff market and live cattle market simultaneously and the interaction of these multiplecommodities may affect the hedging effectiveness of the feedlot. Power and Vedenov (2010) applied LPM_2 criteria to multi-commodity hedging and found the cattlemen's optimal hedging strategy was included speculation in the corn market by taking a long position in corn futures contracts.

To the best of our knowledge, none of this research indicates that hedging in the future market is less effective and causes losses when volume and volatility rise. However, recent research on financialization (Cheng and Xiong, 2014) has found substantial changes to commodity markets, though little attention has been paid to the live cattle market. In this article, we will investigate the optimal hedge ratios using single- and multi-commodity hedging strategies under both MV and LPM_2 criteria, and test the hedging performance of different strategies since 2000.

PROBLEM SETUP

To simulate the feedlot operating process, the operating assumptions in Power and Vedenov (2010) and CME group (2014) are used in this article. The feedlot operator purchases feeder cattle (around 800 pounds per head) and sufficient feed from the spot market. After 17 weeks of feeding, the operator sells the mature live cattle (around 1200 pounds per head) to the spot market, and begins the next feeding operation. Corn is the major feed consumed by cattle, and about 50 bushels of corn will be consumed on average by one head of cattle over the operating period. Soybean meal is a common protein source also consumed by cattle, but it is only a small part of the feed and input, so it is usually not included in the hedging models of cattle feedlot (Power and Vedenov 2010; CME group 2014). Considering the limitations of storage capacity and the uncertainty in the spot market of corn, we assume that feedlot operator purchases the first half of the required corn (25 bushels per head) at the beginning of the operating period, and purchases the second half in the middle of operating period (after 8 weeks).

The problem facing one feedlot operator who grows 100 heads of cattle and decides to hedge the operating risk is considered. The operator will take a long position of 2,500 bushels corn and a short position of 120,000 pounds of live cattle in the futures market. The corn contract will be closed after 8 weeks when purchase corn from the spot market, and the live cattle futures contract will offset at the end of the operating period.

Following Power and Vedenov (2010), the net profit from one operating cycle as described above will be

$$\pi(h) = -Q_0^{FC}p_0^{FC} - p_0^{C}Q_0^{C} - p_8^{C}Q_8^{C} + h_8^{C}Q_8^{C}(f_8^{C} - f_0^{C})$$
$$+p_{17}^{LC}Q_{17}^{LC} + h_{17}^{LC}Q_{17}^{LC}(f_0^{LC} - f_{17}^{LC}) \quad (1)$$

where p refers to the spot prices, f indicates the futures prices, Qs are the quantity purchased or sold, h are the hedge ratios, the superscripts FC, C and LC indicate feeder cattle, corn and live cattle, and the subscripts refers to the weeks of trading happened in the operating cycle. As discussed above, we set $Q_0^{FC} = 80{,}000$ lb, $Q_{17}^{LC} = 120{,}000$ lb and $Q_0^C = Q_8^C = 2500$ bu for the typical feedlot with 100 heads fed. Moreover, the hedge ratios $h = \{h_8^C, h_{17}^{LC}\}$ are not restricted to be positive. $h = \{h_8^C, h_{17}^{LC}\} = \{0, 0\}$ means the operator decides to not hedge the risk and $h^j < 0$ indicates that speculating commodity j would be the optimal strategy.

METHODOLOGY

Hedging Criteria and Optimal Hedge Ratios

To compare the hedging performance of multi-commodity hedging and the single-commodity hedging, we employed both Minimum Variance (MV) criteria and the second order Lower Partial Moment (LPM_2) criteria. MV criteria is widely used in textbooks and in the academic literature as baseline for hedging performance, because it is easy to obtain (Power and Vedenov 2010; Hull 2008). The optimal hedge ratio under MV criteria is

$$h^* = \arg\min_h Var(\pi(h)) \quad (2)$$

where $\pi(h)$ is the net profit of the feedlot.

MV criteria minimizes the deviation from the expected return with equal penalty given to the downside and upside deviation. However, this symmetric penalty does not seem to fit the objective of the commodity hedger in practice. Feedlot operators are more concerned with the downside risk than with the upside return's deviation, if given the same expected return (Power and Vedenov 2010). The downside risk measures, such as the LPM family criteria, are more suitable for the utility of hedgers (Fishburn 1970). In recent years, the second-order LPM criteria is widely used in the agriculture commodity hedging literatures (Liu, Vedenov and Power 2017; Power and Vedenov 2010). The LPM_2 relative to the expected profit $\bar{\pi}$ for a given hedge ratio vector h is

$$LPM_2(h) = \int_{-\infty}^{\bar{\pi}} [\bar{\pi} - \pi(h)]^2 dF(\pi(h)) \tag{3}$$

The optimal LPM_2 hedge ratio is obtained as

$$h^* = \arg\min_h LPM_2(\bar{\pi}, h) = \arg\min_h \int_{-\infty}^{\bar{\pi}} [\bar{\pi} - \pi(h)]^2 dF(\pi(h)) \tag{4}$$

where $\pi(h)$ is the net profit function and $\bar{\pi}$ is the expected profit without hedging, i.e. $\bar{\pi} = E\pi(0)$.

The net profit function faced by a multi-commodity hedger and a single-commodity hedger is slightly different. In the multi-commodity hedging, the net profit function (Eq. (1)) in last section is used in the MV and LPM_2 criteria to generate the optimal joint hedging ratios. But in the case of single-commodity hedging, we assume feedlot operators are only concerned about the net profit from single commodity (corn or cattle) independently. Then net profit for corn-only hedging is

$$\pi^{C'}\left(h_8^{C'}\right) = -p_0^C Q_0^C - p_8^C Q_8^C + h_8^{C'} Q_8^C (f_8^C - f_0^C) \tag{5}$$

and the net profit for cattle-only hedging is

$$\pi^{LC'}\left(h_{17}^{LC'}\right) = -Q_0^{FC} p_0^{FC} + p_{17}^{LC} Q_{17}^{LC} + h_{17}^{LC} Q_{17}^{LC'} (f_0^{LC} - f_{17}^{LC}) \tag{6}$$

If the feedlot operator decides to hedge both corn and live cattle, but hedges them independently, the total net profit is

$$\begin{aligned}\pi^{C'}\left(h_8^{C'}\right) + \pi^{LC'}\left(h_{17}^{LC'}\right) \\ &= -Q_0^{FC} p_0^{FC} - p_0^C Q_0^C - p_8^C Q_8^C + h_8^{C'} Q_8^C (f_8^C - f_0^C) \\ &+ p_{17}^{LC} Q_{17}^{LC} + h_{17}^{LC} Q_{17}^{LC'} (f_0^{LC} - f_{17}^{LC}) \\ &= \pi\left(\{h_8^{C'}, h_{17}^{LC'}\}\right)\end{aligned} \tag{7}$$

This expression of profit has the same format as Eq. (1) but has different hedge ratios. This is important and is provided to allow for convenient comparisons of different hedging strategies at the same magnitude. Therefore, when we mention single-product hedging here and after, we refer to hedging corn and live cattle independently.

Monte Carlo Simulation

Monte Carlo simulation is employed here to find the numerically optimal solution of hedge ratios, because there is no closed-form solution of LPM_2 hedge ratios. The Monte Carlo approach could be used to calculate the integrated value in LPM_2 (h) for any given hedge ratios vector **h**, and then the optimal hedge ratio h*, which maximizes the value of LPM_2 numerically, can be found.

Multi-commodity hedging

To implement the Monte Carlo approach, we first generate the spot and futures shocks for corn and live cattle $\{\varepsilon_t^C, \eta_t^C, \varepsilon_t^{LC}, \eta_t^{LC}\}$ using the historical data. The corn shocks are calculated by the log-difference of initial price at time t $\{p_t^C, f_t^C\}$ and the price 8 weeks ahead $\{p_{t-8}^C, f_{t-8}^C\}$, $\varepsilon_t^C = \log p_t^C - \log p_{t-8}^C$ and $\eta_t^C = \log f_t^C - \log f_{t-8}^C$. Similarly, the shocks for live cattle spot and futures prices are calculated by the log-difference of initial price at t and the price 17 weeks ahead, $\varepsilon_t^{LC} = \log p_t^{LC} - \log p_{t-17}^{LC}$ and $\eta_t^{LC} = \log f_t^{LC} - \log f_{t-17}^{LC}$. A rolling window is then used to generate the shocks in each week.

After all shocks are generated, the shocks series are picked to estimate the marginal probability functions using the kernel density approach of Wand and Jones (1994) and the copula density using the mirror image kernel approach of Charpentier et al. (2007). We then make 10,000 Monte Carlo draws $\{u_i^1, u_i^2, u_i^3, u_i^4\}$ from the estimated kernel copula density following the steps in Cherubini, Luciano and Vecchiato (2004). The draws of joint shocks $\{\varepsilon_{it}^C, \eta_{it}^C, \varepsilon_{it}^{LC}, \eta_{it}^{LC}\}$ are then obtained from converting $\{u_i^1, u_i^2, u_i^3, u_i^4\}$ using the inverse marginal cumulative distribution function.

Next, the realizations of spot and futures prices on the closing dates are generated by multiplying the exponentiation of simulated shocks by the first initial price out of the sample window. For example, the realization of corn spot price in the 8th week is $p_{t+8,i}^C = e^{\varepsilon_{it}^C} p_t^C$. Similarly, the series of realizations of spot and futures prices $\{p_{t+8,i}^C, f_{t+8,i}^C, p_{t+17,i}^{LC}, f_{t+17,i}^{LC}\}$ are generated in the same approach.

Last, the simulated series $\{p_{t+8,i}^C, f_{t+8,i}^C, p_{t+17,i}^{LC}, f_{t+17,i}^{LC}\}$ and the initial price at time t $\{p_t^C, f_t^C, p_t^{LC}, f_t^{LC}, p_t^{FC}\}$ are used to calculate the net profit in Eq. (1) for any given hedge ratio vector h. The Nelder-Mead derivative-free method is then applied to simulate the optimal hedge ratios responding to the MV and LPM_2 criteria (Miranda and Fackler 2004).

A 100-week wide rolling window is applied to compute the optimal hedge ratios for each week. For the tth week (t>100), observations from week t-100 to week t-1 are treated as the historical data, and the spot and future prices observed in the tth week are treated as the initial prices. For example, in the case of first window (which contained the first 100 observations), the 101st observation is treated as the initial price. The procedures described above are then applied window by window to estimate the optimal hedge ratios of each window. Note, the 100-week observation window applied here roughly means the hedgers use the trading data in the past two years to make the hedging decisions.

Single-commodity hedging

In single-commodity hedging, we apply the same procedures as the multi-procedure hedging to simulate the optimal hedge ratios. The subset of realizations of spot and future prices $\{p_{t+8,i}^{C}, f_{t+8,i}^{C}, p_{t+17,i}^{LC}, f_{t+17,i}^{LC}\}$, $\{p_{t+8,i}^{C}, f_{t+8,i}^{C}\}$ and $\{p_{t+17,i}^{LC}, f_{t+17,i}^{LC}\}$, are used directly to calculate the net profit function for corn-only hedging in Eq. (5) and the net profit function for cattle-only hedging in Eq. (6). The Nelder-Mead derivative-free method is again applied to simulate the optimal hedge ratio $h_t^{C'}$ and $h_t^{LC'}$(Miranda and Fackler 2004). The same rolling window approach is employed to estimate the time series of independent hedge ratios.

Measures of Hedging Performance

We use three metrics to compare the hedging performance of different hedging criteria and strategies: hedge effectiveness, expected profit, and expected shortfall. Hedging effectiveness is generally defined as the percentage of risk, as measured by the criteria, offset by hedging relative to the risk without hedging (Ederington 1979). Specifically, the hedging effectiveness of minimum variance criteria is

$$HE_{MV} = 1 - \frac{Var\big(\pi(h^*)\big)}{Var\big(\pi(0)\big)}$$

Hedging effectiveness for LPM_2 is

$$HE_{LPM_2} = 1 - \frac{LPM_2\big(\pi(h^*)\big)}{LPM_2\big(\pi(0)\big)}$$

Expected profit is a primary objective of the feedlot operators, which is calculated as the average of net operating profit $\pi(h^*)$ over the Monte Carlo Draws.

$$E\pi = \frac{1}{N}\sum_{i=1}^{N}\pi^{i}(h^{*})$$

Expected shortfall is employed here as the "coherent risk measure" (Acerbi and Tasche 2002; Artzner et al. 1999). Expected shortfall at $\alpha = A\%$ level measures the expected return on the portfolio of the worst A% of cases. To be consistent with the literature on Value-at-Risk (VaR), the level of $\alpha = 5\%$ is selected here (Jorion 2000). Expected shortfall at α level for a continuous distribution with the probability density function $f(\cdot)$ is

$$ES = -\frac{1}{\alpha}\int_{-\infty}^{x_\alpha} x f(x)dx$$

where $\alpha = \int_{-\infty}^{x_\alpha} f(x)dx$.

DATA

To implement the problem set up in the previous section, the corn futures price of Chicago Board of Trade (CBT, CME group) and the live cattle futures price of Chicago Mercantile Exchange (CME) are used. The prices of Corn Number 2 Yellow in Central Illinois (underlying assets of corn futures) and US Department of Agriculture (USDA) 5 Area weighted average price of live cattle (underlying assets of live cattle) are selected as spot prices. Chicago Mercantile Exchange (CME) feeder cattle index (underlying assets of feeder cattle futures) is used as the proxy for feeder cattle spot price. All of the data are obtained from Thomson Reuters Datastream for the period from January 2001 to December 2016. Limited by the data frequency of live cattle spot price, data are converted to weekly frequency by sample the prices on Wednesday[1]. The summary statistics of the raw data are presented in Table 1. And the time series of the data are presented in Figure 1.

[1] Wednesday is selected, because it is less likely to be holiday on which markets are closed. If the data on Wednesday is not available, the data on the next trading day will be used.

Table 1: Summary Statistic of Corn and Live Cattle's Spot and Futures Prices, 2001-2016

	Mean	Standard Deviation	Skewness	Kurtosis	Min	Max
Corn spot price ($/bu)	3.7454	1.7231	0.8587	2.6767	1.645	8.48
Corn futures prices ($/bu)	3.9206	1.6367	0.782	2.6114	1.9575	8.3475
Live cattle spot price ($/lb)	1.0182	0.2636	0.7762	2.7012	0.6203	1.7138
Live cattle futures price ($/lb)	1.0206	0.2545	0.5904	2.3559	0.6068	1.702
Feeder cattle prices ($/lb)	1.2382	0.3907	1.2661	4.0061	0.7376	2.4499

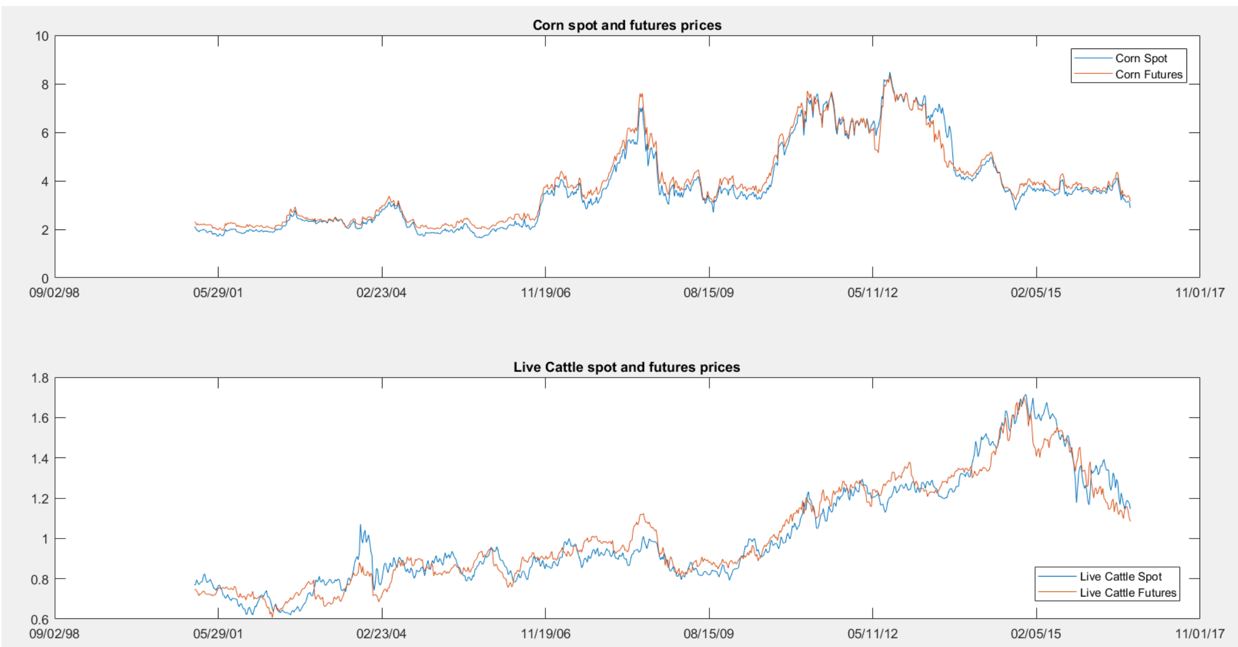

Figure 1: Spot and future prices of corn and live cattle, 2001-2016

RESULTS

Optimal hedge ratios for each 100-week window from January 2001 to December 2016 are calculated for both MV and LPM_2 criteria and are plotted in Figure 2 and Figure 3. For each hedge criteria, we calculated the hedge ratios under both single-commodity hedging strategy and multi-commodity hedging strategy.

Generally, the single-commodity hedge ratios of corn and live cattle are very normal and stable (hedge ratios closing to 1) under both MV and LPM_2 criteria. Under multi-commodity hedging strategy, the hedge ratios of live cattle approach the single-commodity hedge ratios of live cattle, while the hedge ratios of corn vary over time.

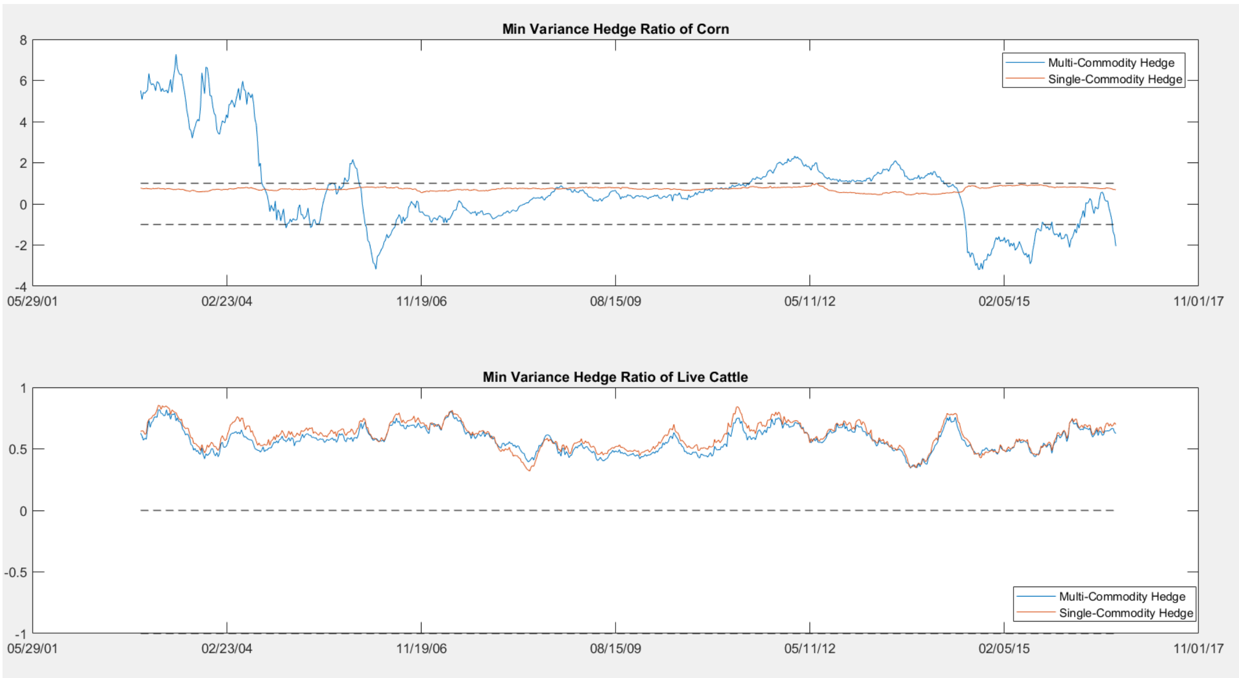

Figure 2: Hedge ratios using MV criteria, 2002-2016

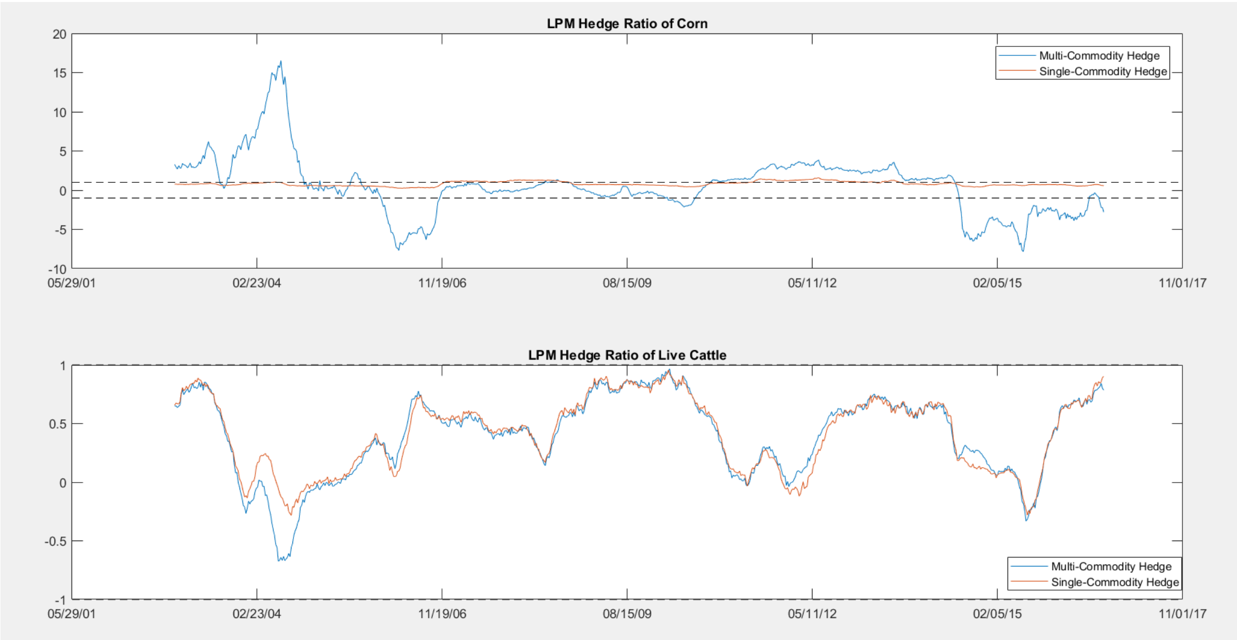

Figure 3: Hedge ratios using LPM_2 criteria 2002-2016

To explain the difference between hedge ratios under single- and multi-commodity hedging strategies, we employed the correlation coefficients across commodities and across spots and futures prices shocks. Hull (2008) discussed this in the single-commodity hedging case, the optimal hedge ratios are dominated by the correlations between spot and future return shocks of the commodity, at least for the MV criteria. Liu et al. (2017) pointed out that in the multi-commodity hedging strategy, the cross-dependence between the spot and future price shocks of different commodities does affect the hedge ratios. Kendall's τ and Pearson's ρ are selected to calculate the cross-dependence among the 4 series of shocks (corn and live cattle's spot and future price shocks). Pearson's correlation coefficient (ρ) is widely used in measuring the linear correlation between two variables, which would be a more approaching measure for the hedging behavior of MV criteria. While Kendall's rank correlation coefficient (τ) is better in capturing the tail dependence (Cherubini et al. 2004), which would be more suitable to test the behavior of LPM_2 hedging. Both Kendall's τ and Pearson's ρ are calculated for cross relations among corn and live cattle's spot and futures price from January 2001 to December 2016 using the same rolling window approach as we used to calculate hedge ratios. The summary statistics of Pearson's correlation coefficient and Kendall's rank correlation coefficient are listed in Table 2.

Table 2: Summary Statistics of Dependence Coefficients

Panal A: Summary Statistics of Pearson's Correlation Coefficient

	Corn.S vs Corn.F correlation	Corn.S vs LC.S correlation	Corn.S vs LC.F correlation	Corn.F vs LC.S correlation	Corn.F vs LC.F correlation	LC.S vs LC.F correlation
Min	0.7468	-0.6040	-0.4462	-0.6003	-0.5129	0.3959
Max	0.9911	0.3256	0.3674	0.3806	0.4065	0.8490
Mean	0.9346	-0.0432	-0.0762	-0.0696	-0.0661	0.6826
sd	0.0663	0.2104	0.1997	0.1999	0.2098	0.0937

Panal B: Summary Statistics of Kendall's Rank Correlation Coefficient

	Corn.S vs Corn.F tau	Corn.S vs LC.S tau	Corn.S vs LC.F tau	Corn.F vs LC.S tau	Corn.F vs LC.F tau	LC.S vs LC.F tau
Min	0.6488	-0.3972	-0.3766	-0.3790	-0.4154	0.2638
Max	0.9103	0.2558	0.2764	0.2566	0.2885	0.6416
Mean	0.8235	-0.0210	-0.0849	-0.0307	-0.0762	0.4855
sd	0.0604	0.1404	0.1349	0.1142	0.1303	0.0782

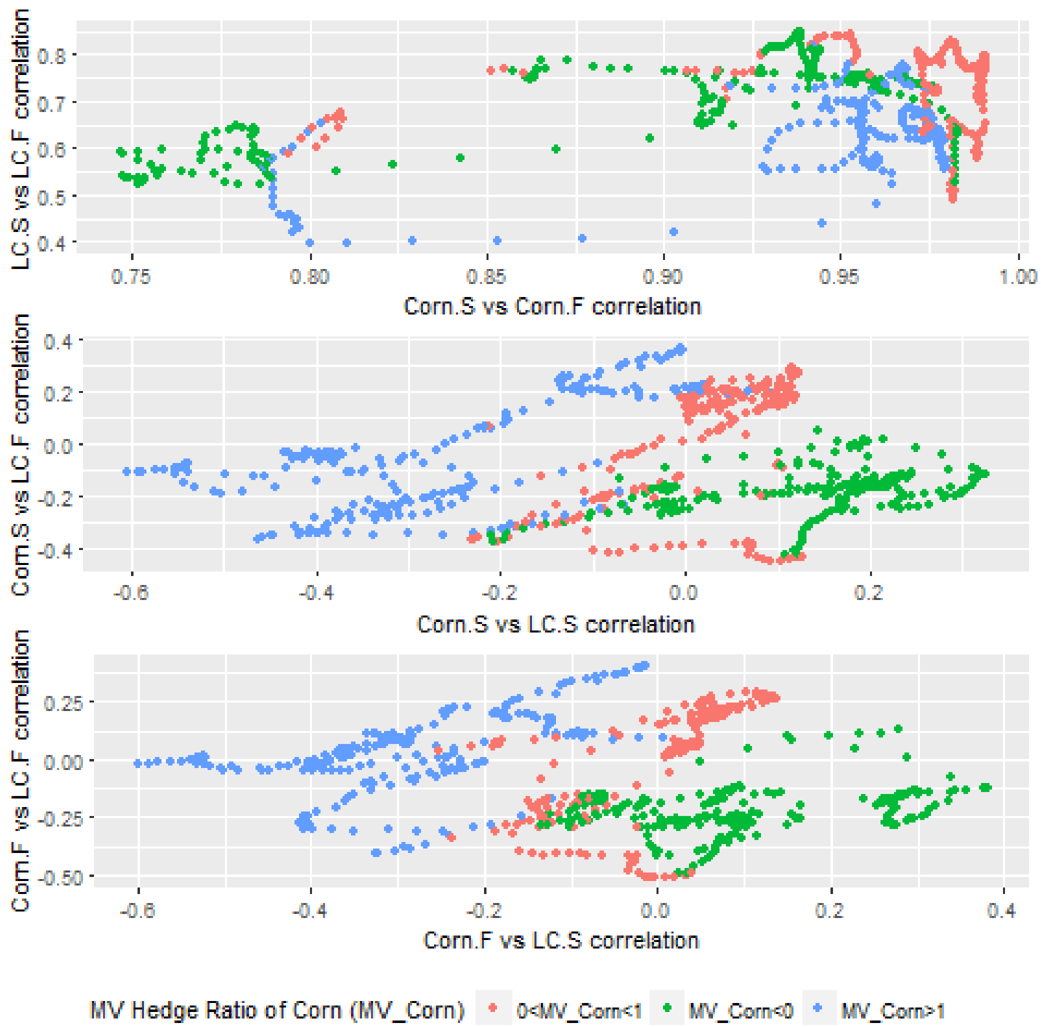

Figure 4: Scatterplot of Pearson's correlation coefficients colored by MV hedge ratio of corn

To test the cross dependence effects on the optimal multi-commodity hedge ratios visually, we first group the optimal multi-commodity hedge ratios of corn into high (greater than 1), medium (between 0 and 1) and low groups (negative), and then draw the scatterplot of dependence coefficient and color it by groups.[2] Figure 4 gives the scatterplot of the Pearson's correlation coefficients colored by the multi-commodity hedge ratios of corn under MV criteria. Roughly,

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[2] Since only the corn hedge ratio moved dramatically over time, we plotted the scatterplots colored by optimal corn hedge ratios

the correlations between corn and live cattle cross price shocks have clear effects on the optimal hedge ratios. The optimal hedge ratios increase with the correlation between live cattle futures shocks and corn price shocks (both spot and future price shocks), and decrease with the correlation between live cattle spot shocks and corn spot and future price shocks. The effects of spot and futures correlation of corn and live cattle on optimal hedge ratios of corn is not very clear from the scatterplot.

Figure 5: Scatterplot of Kendall's rank correlation coefficients (Kendall's τ) colored by LPM_2 hedge ratio of corn

A scatterplot of Kendall's tau colored by optimal LPM_2 hedge ratios of corn is shown in Figure 5. Similar to the results of MV hedge ratios of corn, Kendall's rank correlations between corn and live cattle dominate the trend of corn hedge ratio under LPM_2 criteria, while the effects of Kendall's tau between spot and future prices of corn and live cattle on LPM_2 hedge ratios of corn are not obvious.

To test the effect of cross dependence on optimal hedge ratios formally, we estimate a regression of optimal multi-commodity hedge ratios on the cross dependence coefficients, and show the result in Table 3.

Table 3: Regression Results of Multi-commodity Hedge Ratios on Dependence Coefficients

Panel A: Regression Results of MV Multi-commodity Hedge Ratios on Pearson's ρ

	MV Multi-commodity Hedge Ratios	
	Corn	Live Cattle
Corn.S vs Corn.F correlation	2.336***	0.319***
Corn.S vs LC.S correlation	-8.895***	0.144*
Corn.S vs LC.F correlation	4.234***	0.157*
Corn.F vs LC.S correlation	0.705	-0.275***
Corn.F vs LC.F correlation	-2.428**	-0.188**
LC.S vs LC.F correlation	-2.385***	0.383***
Adjusted R-squared	0.714	0.975

Panel B: Regression Results of LPM_2 Multi-commodity Hedge Ratios on Kendall's τ

	LPM_2 Multi-commodity Hedge Ratios	
	Corn	Live Cattle
Corn.S vs Corn.F tau	3.134***	0.114
Corn.S vs LC.S tau	7.029	0.063
Corn.S vs LC.F tau	-10.227**	-0.067
Corn.F vs LC.S tau	-27.929***	-0.148
Corn.F vs LC.F tau	12.196**	0.541
LC.S vs LC.F tau	-5.347***	0.693***
Adjusted R-squared	0.560	0.595

*** Significant at 0.1% level
** Significant at 1% level
* Significant at 5% level

The regression results support our observation from the scatterplot and explain the difference between optimal single-commodity and multi-commodity hedge ratios. The regression coefficients of live cattle on dependence coefficients indicates that the optimal MV hedge ratios of live cattle are dominated by the spot-future shocks' Pearson's correlation of corn and live cattle, while the LPM_2 optimal hedge ratios are only driven by Kendall's rank correlation between spot and futures prices shocks of live cattle. Recall that the optimal single-commodity hedge ratios are only driven by the dependence coefficients between spot and futures shocks of that commodity. From Table 2, we observe that the spot-future correlation of corn price shocks is relatively stable and would have smaller effects on the optimal hedge ratio of live cattle. Therefore, the live cattle multi-commodity hedge ratios are also majorly dominated the correlation coefficients between spot and future price shocks of live cattle, which explained the similarity between the multi-commodity and single-commodity live cattle optimal hedge ratios. However, the multi-commodity optimal hedge ratio of corn under both MV and LPM_2 criteria are significantly driven by the cross dependence between corn and live cattle instead of the correlation between spot and futures shocks of corn. The different driven factors determined that the difference between multi-commodity and single-commodity optimal hedge ratios of corn. On the mechanism side, it is also expected that multi-commodity hedge ratios of corn varies more than that of live cattle over time. The algorithm we presented is used to find the hedging ratios which would minimize the risk of total profit under different risk criteria. In the case of the feedlot operation, corn only presents a small proportion in the net profit of joint hedging. Adjusting the small component (corn cost) is always easier and more efficient than the large component (live cattle) to find the optimal value. Therefore, most of the cross dependence effects of the multi-commodity hedging system are reflected by the varied corn hedge ratios.

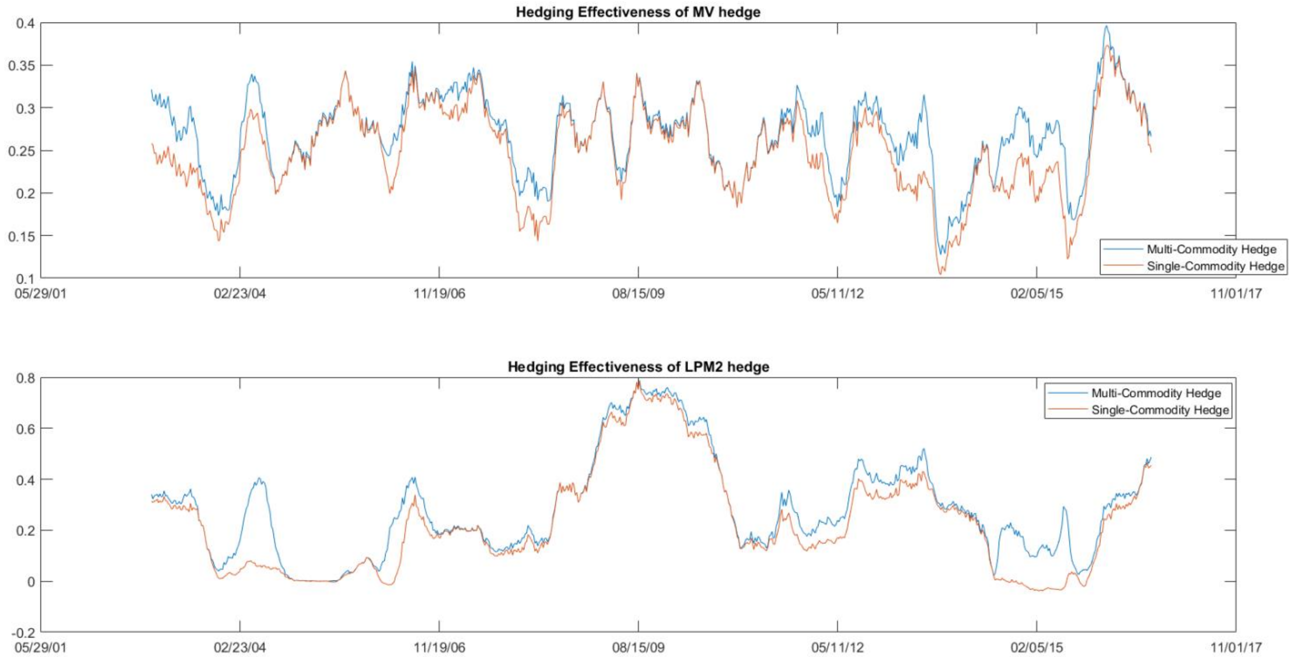

Figure 6: Hedging effectiveness of single-commodity and multi-commodity hedging strategies under MV and LPM$_2$ criteria, 2001-2016

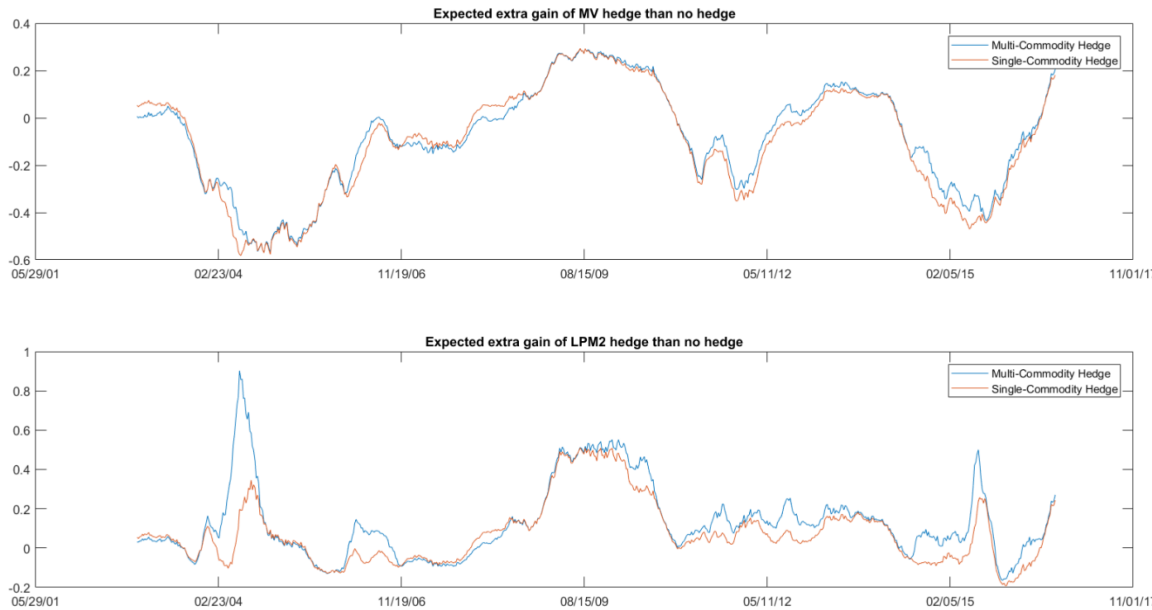

Figure 7: Extra gain from single-commodity and multi-commodity hedging strategies than that from non-hedging strategy under MV and LPM_2 criteria, 2001-2016

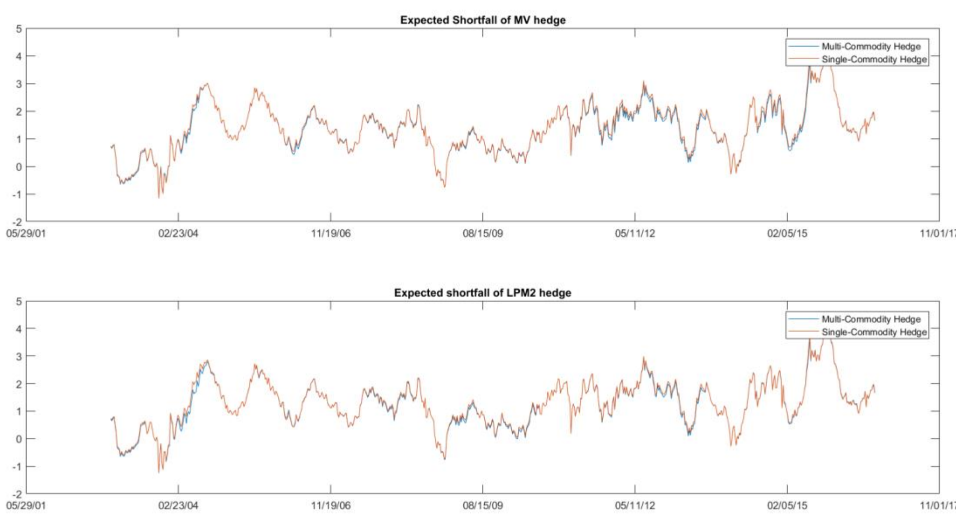

Figure 8: Expected Shortfall of single-commodity and multi-commodity hedging strategies under MV and LPM_2 criteria, 2001-2016

The second question we want to answer in this article is whether or not the multi-commodity hedging is better than the single-commodity hedging, since multi-commodity hedging addresses the dependence between different commodities, and both hedging strategies are better than a non-hedging strategy. Figure 6 through Figure 8 and Table 4 through Table 6 present the overall single- and multi-commodity hedging performance under two different criteria.

Generally, multi-commodity hedging strategy performs better than single-commodity hedging under both criteria, which means a multi-commodity strategy yields higher hedging effectiveness, higher profit, and a lower expected shortfall. Also, both multi-commodity hedging and single-commodity hedging tend to perform better than a non-hedging strategy in most cases. In term of hedging effectiveness, the total risk (measured by variance or second lower partial moment) faced by the feedlot operator decreased under all hedging strategies, except single-commodity hedging under LPM_2 criteria, relative to a non-hedging strategy. Also, the multi-commodity hedging strategy tended to improve hedging effectiveness, which may be because it incorporates the dependence between different commodities into the system.

Interestingly, in 62 out of the 718 windows, the single-commodity hedging under LPM_2 criteria enlarged the overall downside risk faced by the hedger, which supports incorporating the dependence between commodities in the hedging strategy.

Table 4: Hedging Effectiveness Using Multi-commodity Hedging strategy and Single-commodity Hedging Strategy under Different Criteria and Their Difference (Higher Values Indicate Better Performance).

Panel A: Hedging Effectiveness under MV Criteria			
	Single-Commodity Hedging	Multi-Commodity Hedging	Difference Between Multi- and Single-Commodity hedging
Min	10.63%	12.55%	0.00%
Max	38.21%	40.00%	9.23%
Mean	24.72%	26.76%	2.03%
SD	5.22%	4.72%	2.00%

% Positive	100.00%	100.00%	100.00%
Panel B: Hedging Effectiveness under LPM_2 Criteria			
	Single-Commodity Hedging	Multi-Commodity Hedging	Difference Between Multi- and Single-Commodity hedging
Min	-3.82%	0.01%	0.00%
Max	77.80%	78.04%	35.31%
Mean	22.83%	28.11%	5.27%
SD	20.19%	19.21%	6.69%
% Positive	91.36%	100.00%	100.00%

Table 5 shows the profit obtained from hedging and non-hedging strategies. There are more than 60% windows losing more money than non-hedging strategy under MV criteria. But if the hedger chose to use LPM_2 criteria, in more than 60% of the windows, they would gain from hedging, especially in most of windows during year 2015-2016. These results directly contradict the opinions of the National Cattlemen's Beef Association. Moreover, multi-commodity hedging could help improve the profit in more than 70% of the tested windows, regardless of the criteria used.

Table 5: Net Profits of Feeding 100 Heads Live Cattle Using Non-hedging, Multi-Commodity Hedging and Single-Commodity Hedging Strategies under Different Criteria and Their Difference (10k USD$) (Higher Values Indicate Better Performance).

Panel A: Profit under MV Criteria						
	Non-Hedging (N)	Single-Commodity Hedging (S)	Multi-Commodity hedging (M)	(M-S)	(M-N)	(S-N)
Min	-1.874	-2.213	-2.184	-0.065	-0.554	-0.590
Max	3.720	3.513	3.492	0.142	0.292	0.293
Mean	0.699	0.598	0.614	0.016	-0.085	-0.101
SD	0.788	0.804	0.795	0.039	0.214	0.228
% Positive				70.47%	38.72%	38.44%
Panel B: Profit under LPM_2 Criteria						
	Non-Hedging (N)	Single-Commodity Hedging (S)	Multi-Commodity hedging (M)	(M-S)	(M-N)	(S-N)
Min	-1.874	-1.942	-1.889	-0.063	-0.155	-0.194
Max	3.720	3.687	3.68	0.729	0.901	0.516

Mean	0.699	0.774	0.828	0.053	0.129	0.075
SD	0.788	0.784	0.785	0.098	0.187	0.159
% Positive				72.70%	78.83%	64.90%

The expected shortfall measure provides more evidence that hedging could improve the situation of feedlot operators. And, using this measure, multi-commodity hedging strategy performs better than the single-commodity hedging as well. Hedging could decrease the expected shortfall at 5% level of net profit of feedlot with 100 heads live cattle in more than 60% windows we built under MV criteria. If the LPM_2 criteria are applied, only in around 10% of the overall windows the expected shortfall could not be reduced. This is expected because the LPM_2 criteria focuses more on the downside risk, which is also measured by the expected shortfall. Similar to other measures, the multi-commodity hedging could also lead to better performance than the single-commodity hedging, regardless of the criteria used.

Table 6: Expected Shortfall of Feeding 100 Heads Live Cattle Using Non-hedging, Multi-Commodity Hedging and Single-Commodity Hedging Strategies under Different Criteria and Their Difference (10k USD$) (Smaller Values Indicate Better Performance).

Panel A: Expected Shortfall under MV Criteria

	Non-Hedging (N)	Single-Commodity Hedging (S)	Multi-Commodity hedging (M)	(M-S)	(M-N)	(S-N)
Min	-1.146	-1.162	-1.148	-0.212	-0.499	-0.493
Max	4.500	4.546	4.548	0.064	0.279	0.335
Mean	1.448	1.370	1.331	-0.039	-0.117	-0.078
SD	0.841	0.882	0.872	0.052	0.183	0.190
% Negative				76.74%	73.96%	63.79%

Panel B: Expected Shortfall under LPM_2 Criteria

	Non-Hedging (N)	Single-Commodity Hedging (S)	Multi-Commodity hedging (M)	(M-S)	(M-N)	(S-N)
Min	-1.146	-1.231	-1.251	-0.379	-0.607	-0.599
Max	4.500	4.486	4.513	0.061	0.093	0.083
Mean	1.448	1.289	1.256	-0.032	-0.192	-0.159
SD	0.841	0.856	0.859	0.053	0.163	0.150
% Negative				74.51%	91.36%	88.44%

CONCLUSION

In this article, we investigate the effectiveness of the hedging strategies in the cattle market. A Monto Carlo procedure and moving window approach are used in this article to calculate the optimal hedge ratios under MV and LPM_2 criteria for each 100-week rolling window from January 2001 to December 2016. Single-commodity hedging strategy (hedging corn and live cattle independently) and multi-commodity hedging strategy are applied and compared in this article.

Under single-commodity hedging, the hedge ratios of corn and live cattle vary from 0 to 1 in most windows. Under the multi-commodity hedging, the hedge ratios of live cattle are approaching to the single-commodity hedge ratio of live cattle, but the corn hedge ratio varies from -3.27 to 7.03 under the MV criteria and -7.99 to 16.45 under the LPM_2 criteria.

To explain the difference of hedge ratios, we regress the optimal multi-commodity hedge ratios on the dependence coefficient (Pearson's rho and Kendall's tau). The regression result shows that the multi-commodity hedge ratios of corn are dominated by the cross dependence between corn and live cattle under both MV and LPM_2 criteria, which is not involved in the single-commodity hedging strategy. The multi-commodity hedge ratios of live cattle are led by the spot-future dependence of live cattle, which is also the dominate factor in single-commodity hedging (Hull 2008). On the other side, adjusting the small component (corn) of net profit and risk is always easier and more efficient than adjusting large component (live cattle) to find the optimal value. Therefore, most of the dependence between corn and live cattle is reflected by the corn hedge ratios in the multi-commodity hedging.

Performance of these hedging strategies is also tested in this article using the measures of hedging effectiveness, net profit and expected shortfall. Generally, hedging in the futures market benefits the feedlot operators, which increases hedging effectiveness and decrease expected shortfall in most cases regardless of the criteria used. In term of the profit measure, net profit is improved in around 38% of the overall 718 rolling windows, if the MV criteria are applied. Since purpose of hedging is to reduce the risk faced by the feedlot, instead of increasing the profit, this result is acceptable. However, under the LPM_2 criteria, the profit could be increased in at least 466 windows (out of 718 windows, or 64.9%) relative to the non-hedging strategy. This means if LPM_2 criteria are chosen, the cattlemen are likely to increase profit and reduce risk from hedging, which contradicts the opinion in the NCBA letter to CMB (Ellis and Greiman 2016). Furthermore, under all of the three measures of hedging performance, multi-commodity hedging performs better than single-commodity hedging, no matter criteria chosen.

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