

THESIS

CATTLE FEEDING HEDGING AND CASH MARGIN ANALYSIS

Submitted by

Holden Miller Ramey

Department of Agricultural and Resource Economics

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Master's Committee:

Advisor: Stephen R. Koontz

W. Marshall Frasier

John J. Wagner

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ABSTRACT

CATTLE FEEDING HEDGING AND CASH MARGIN ANALYSIS

Historical cattle feeding margins offered through multiproduct hedging, single commodity hedging, and cash markets are determined and compared. Expected margins result from hedging in the commodity futures markets, while actual margins are garnered in the cash market. Price and production data are used to construct a cattle feeding scenario representative of a typical U.S. cattle feeder. Margin equations that account for price, weight, and costs of feeding cattle are developed and adapted to accommodate each type of margin. Actual costs from feedlot closeout data are applied in margin calculations and are also used to construct a model to estimate costs not yet known. Commodity futures are adjusted using both actual and expected methods of basis.

This research's primary objective is to determine the mean and risk associated with expected margins generated by hedging strategies and cash margins. Furthermore, insight is acquired on margin opportunities offered by cash and commodity futures markets. Results obtained by this research will be analyzed primarily, using the mean-variance framework. Also, the distribution of expected and actual margins was evaluated and discussed.

This study provided a necessary update to research that had previously been done analyzing cattle feeding margins. The goal was to benefit individuals involved in the cattle

feeding segment and the U.S. beef industry. This work helped provide cattle feeders with the necessary information to improve cattle feeding margins through well-informed risk management decisions. Implementing the right strategy at the right time to secure margins has many important benefits, though the most important one is the financial soundness of cattle feeding entities.

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CHAPTER 1: INTRODUCTION

Cattle feeding is a vital segment of the United States Cattle Industry. In the beef production chain, cattle feeding is one of the later steps, where calves or feeder cattle are fed until they reach market weight. Once cattle arrive at this point, they are sold to beef packers for processing (Davis, 2021). While the process may seem straightforward, the cattle feeding sector often faces significant risk. Cattle performance and weather are risks to production that can jeopardize a cattle feeder's investment. However, another form of risk faced by the cattle feeding segment is price risk. Price risk stems from commodity prices constantly changing to respond to dynamic market fundamentals and economic factors. Figure 1 illustrates historical average returns to cattle feeders.

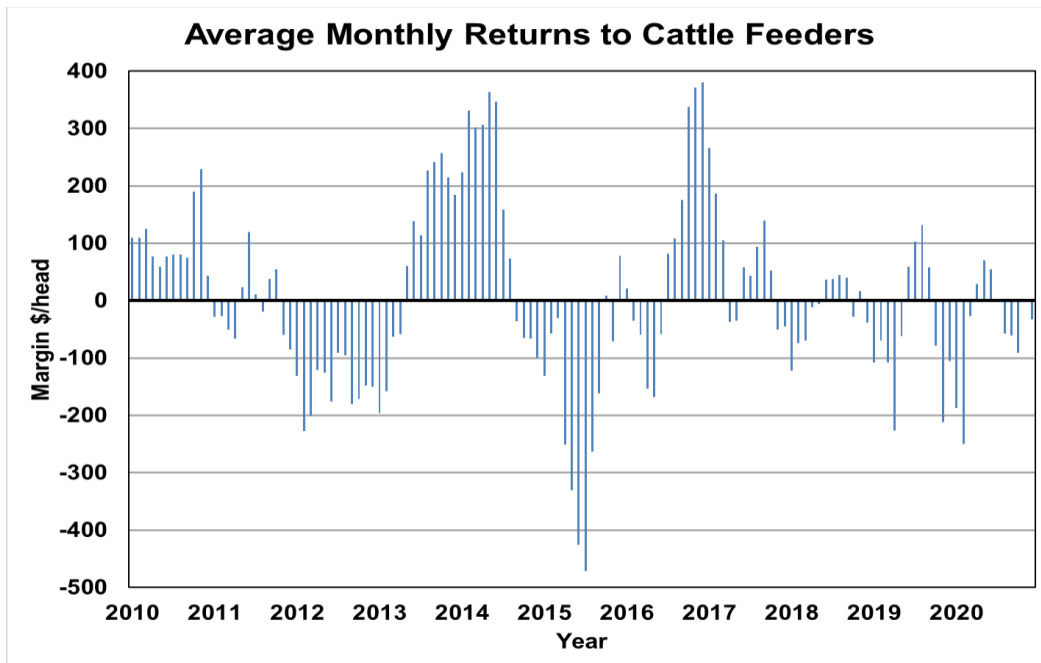


Figure 1: Average Returns to Cattle Feeders

The variability seen in margins is driven, in large part, by price risk. Cattle feeders must endure price risks in their output market. There are also adverse price shifts within their input markets as well (Noussinov & Leuthold, 1999).

Cattle feeding margins have exhibited volatility overtime and have a long-run average close to zero. The nature of cattle feeding requires that an individual be involved in multiple commodity markets. The markets of key concern are feeder cattle, corn, and live cattle. Feeder cattle and corn represent the two most significant inputs to production, while live cattle are the output. Uncertain margins are problematic for cattle feeding entities, especially when evaluating the financial wellbeing of their business. Cattle feeders engage in risk management practices to avoid or minimize losses. (Schroeder & Hayenga, 1988). There are several tools cattle feeders can employ to help achieve these goals, hedging in the commodity futures market is one of the more widely used options.

Futures hedging has been a widely applied risk management strategy in the cattle feeding segment since 1964 (Gorman et al., 1982). This practice uses commodity futures markets traded on the Chicago Mercantile Exchange (CME). A hedge in the futures market allows an individual the opportunity to “secure” a price in advance of taking a position in the physical or cash markets. Two risk management strategies are applied to evaluate potential margins the market is offering. The first is a portfolio hedging approach known to the cattle feeding sector as the “Cattle Crush.” This approach derives its name from another portfolio or multiproduct hedging strategy used by soybean processors known as the soybean crush. The name of this strategy was derived from the crushing process used by soybean processors to transform soybeans into soybean meal and oil. (Simon, 1999). The soybean crush allows soybean processors to secure margin in advance of taking physical positions. The cattle crush involves simultaneous hedges in

key markets mentioned previously. To execute the cattle crush, one would place buys (long positions) in the feeder cattle and corn markets and a sell (short position) in the live cattle market. A cattle crush is employed to secure margin before cattle are purchased to be placed on feed. The second risk management strategy used in this research is live cattle hedging, a hedge in a single commodity market. This approach consists of selling, taking a short position, in the futures market for live cattle. Though this risk management strategy can be used before placing cattle on feed, this research applies the strategy exclusively during the feeding period once feeder cattle have been placed.

The outcomes of this research are intended to benefit U.S. cattle feeders by providing insight into the following questions. When do markets offer profitable margins, and how often do they occur? Should a producer hedge to secure a margin today or wait? What are optimal margins, and when can they be expected? Depending on market conditions, what strategy presents optimal margins? Why should an individual consider futures hedging? Answers to these questions would assist cattle feeders in making better and more informed risk management decisions.

1.1 Objective

The objective of this research is to identify the mean and variance of expected cattle feeding margins through cattle crush hedging, live cattle hedging, and actual margins offered by the cash market. The distribution of expected margins from both hedging strategies and actual margins from the cash market will be evaluated. This analysis will generate insight into margin opportunities offered by both the cash and futures markets. Additionally, this research will look at how basis variability affects margins. To achieve these objectives, a hypothetical cattle feeding scenario is constructed using reported data from various sources. Opportunities for

optimal margins may exist before or at any point during the feeding period. For cattle feeders knowing when markets present optimal margins would be beneficial in helping improve margins and ensure continuity of operations.

1.2 Organization of the Thesis

The next chapter consists of a literature review of various works in feedlot margins analysis and risk management strategies. Chapter 3 details the data used in this research including background and origins. Chapter 4 discusses the methods used to construct margin matrices and calculate margins garnered by each strategy. Techniques used to account for factors such as cost of gain and basis will also be discussed in this section. Chapter 5 outlines margin results and compares strategies overtime and evaluates each individual strategy. Finally, chapter 6 delivers concluding comments, research implications and future directions for this research.

CHAPTER 2: LITERATURE REVIEW

This literature review consists of four sections. The first discusses what previous literature has discovered about cash cattle feeding margins. Also, background is provided on the commodity futures market and the benefits that can come from its application. In section 2, literature that has investigated the use of both live cattle hedging and cattle crush hedging is presented. The theory behind multiproduct hedging is covered here as well. Section 3 contains studies that have previously used mean-variance analysis with margin evaluation being a primary objective. In the closing section of this chapter literature contributions made by this research are summarized.

2.1 Variable Cash Margins

Cash margins occur once all cash or physical prices become known. In cattle feeding, this means a cash margin is only known once live cattle, are marketed. As mentioned in the introduction price risk in physical commodity markets results in margins that can be negative or very unpredictable. Gorman et al. (1982) found the average cash return over the period studied from 1971 to 1977 to be -\$24.50 per head. Moving forward in time, Schroeder and Hayenga (1988) find that from 1978 to 1985 cash margins had improved to \$9.08 per head. However, cash margins had the largest standard deviation at \$68.75 per head. Cash margins at the low end of the range were -\$129.83 while the high end was marked by \$216.24, on a per head basis.

The establishment of the commodity futures markets served two purposes. First, commodity futures markets were to be used as a price discovery mechanism for various

commodity products. Second, futures markets were to assist in managing price risk faced by those individuals or entities that needed to buy or sell commodities (CME Group, 2017).

Hedging in the commodity futures markets allows producers to not be fully dependent on cash margins. Much literature has concluded that the use of the commodity futures market can benefit cattle feeders. Whether an individual chooses to engage in multiproduct hedging or single commodity hedging, risk management has been shown to increase average margins and reduce variance when compared to scenarios where no risk management was implemented (Noussinov & Leuthold, 1999). Gorman et al. (1982) finds that even if a hedging strategy does not always lead to positive margins, it could lower the burden of losses by about half. Regularly circumventing all hedging approaches carries with it, a significant cost to cattle feeders (Leuthold & Mokler, 1978).

2.2 Risk Management

Risk management has garnered significant attention from researchers over time because of its importance to those entities involved in commodities. Much of it centers around finding the optimal strategy that will limit risk and increase average returns. Kim et al. (2010) considers single commodity hedging of the output price to secure margin for grain producers. Producers' utility functions are used to analyze the performance of profit margin hedging. Margin hedging was measured against a strategy where hedging was automatically executed regardless of market conditions. Also used in comparison was a scenario where the producer only took the cash margin offered when grain was marketed. Strategies were assessed using various levels of required utility, ranging from low to high. Single commodity hedging to secure profit margin was found to be a successful practice, even at elevated utility requirements.

Hedging live cattle, or single commodity hedging for cattle feeders has been evaluated by several authors. Hayenga et al. (1984) uses single commodity hedging to determine the number of opportunities a cattle feeder had to hedge a profitable margin. Live cattle hedges were examined daily throughout the six months cattle were on feed. The authors find that commodity futures markets provided persistent opportunities to secure a lucrative margin. However, profitable opportunities certainly were not offered all the time. But during times when positive margins were unavailable, live cattle hedging could help limit negative cash margins. Gorman et al. (1982) focus their research on live cattle hedging as well. Like other research in the area, a cattle feeding operation was simulated. However, unique to this research was their access to actual feedlot data. From this data, observed costs of gain were used in calculations to determine cash margins generated by pens of cattle fed. Single commodity hedging strategies included always hedging, hedging in break evens, and use of technical analysis to signal when cattle should be hedged. Though some strategies were found to be more lucrative than others, in general, implementation of a well thought out strategy was consistently superior to having no strategy at all.

Schroeder and Hayenga (1988) look at risk management strategies such as cash markets, naïve hedging, put options, and use of forecasts to inform either hedging or options decisions. For both the options strategy and the hedging strategy only the live cattle futures market was used. To conduct their analysis, a theoretical cattle feeding scenario was set up, representative of a midwestern cattle feeding operation from 1978 to 1985. It is determined that when the cattle market tracked with its normal seasonal pattern, futures hedging exceeded in comparison to futures options. However, this was not the case when cattle markets experienced strong upward momentum. Overall, cattle feeders better managed risk when favorable margins were secured.

This conclusion is consistent with other work that deemed futures and options hedging as effective risk management tools. However, this research cautioned that it is critical to keep basic economics in mind. The cautionary principle referenced here is a market-clearing price. For every producer, hedging does not guarantee greater prices than the price determined by supply and demand fundamentals (Tomek, 1987).

Multiproduct hedging has been assessed by several authors as well. Initially, the strategy originated from Portfolio Theory developed by Markowitz in 1952 and 1959. This theory is centered around the idea of diversifying investments to lower risk. Multiproduct hedges like the cattle crush are treated as a single investment, even though the risk manager is hedging multiple commodities. This portfolio of hedges has been shown to increase average margins and reduce risk (Peterson & Leuthold, 1987). Economic theory presumes that an organization knows the price of their respective outputs. This is a strong presumption in practice, but especially within agriculture markets where significant price shifts can occur over short periods of time. Portfolio theory for risk managers allows them to consider an expected margin well in advance of committing to feeding cattle. Therefore, allowing better decision making, especially as it pertains to selecting investments (Markowitz, 1991).

As previously mentioned, one form of multiproduct hedging is the soybean crush which was used and evaluated in research by Fackler and McNew (1993). Their primary purpose was to establish optimal hedge levels for individuals managing risk using an assortment of futures and cash markets. Once levels were determined they were implemented to assess the strategy from the standpoint of a soybean crushing facility. These authors' results are supportive of the concept that risk managers in the soybean crushing business, can benefit from the use of multiproduct hedging. In comparison to not hedging at all, use of the soybean crush was able to reduce

variance by over half. Transitioning into multiproduct hedging use in cattle feeding, comparable results have been attained. Cattle crush hedging allows cattle feeders more opportunities to secure a margin, rather than accepting margins in cash markets. It was found to perform during times of increasing as well as decreasing prices. In low-price environments, like was exhibited between 1974 and 1976, the cattle crush reduced variation by just over seven dollars per head and helped avoid most negative margins. During times of elevated prices, like those experienced in 1978, this hedging strategy still offered increased margins and reduced variation when compared back to cash margins (Spahr & Sawaya, 1981).

Risk management strategies have been evaluated within several research endeavors. Some have managed to draw conclusions and have the necessary results to do so. Multiproduct hedging has been favored, because of the ability to reduce risk (Leuthold & Mokler, 1978; Spahr & Sawaya, 1981; Fackler & McNew, 1993). Others have found increased margins using live cattle hedging (Shafer et al., 1978; Schroeder & Hayenga, 1988). While some research may have overlap between periods studied, it is important to observe, many do not. The optimal hedging strategy is likely to vary across time depending on fundamental factors impacting the industry. In one subset of years, beef cow inventories may be reduced creating a shortage of live cattle for harvest, thus driving prices higher. In a different span of years, beef demand may contract causing lower prices. It is expected that the outcomes of this research will be similar, regarding the fact results will be impacted by the current state of the U.S. cattle industry.

2.4 Mean-Variance Analyses

This research uses mean-variance analyses to evaluate both expected and actual margins. This type of analyses has been conducted as part of many studies, especially those focusing on the cattle feeding sector. Spahr and Sawaya (1981) use mean-variance analysis to evaluate the

effectiveness of cattle crush hedging. This work was conducted over the period from 1974-1978 where weekly futures prices were used in crush hedging margin equations. Futures prices were not basis adjusted while corn price and assumed corn needs were used to simulate ration costs. All other costs were held constant in their model. Margins are examined in the 17 weeks leading up to placing cattle on feed to determine if the crush hedge met various prespecified margin requirements. If margin requirements were attained hedges were executed, if not the search continued until cattle were placed, at which point cash positions would be taken.

Similar mean variance analyses conducted around the same period was done by Shafer et al. (1978) who looked at the period of 1972 through 1976. Margins from the multiproduct hedging strategy were evaluated daily for the two months preceding the purchase of feeder cattle. Margin equations developed by this research are like those constructed by Spahr and Sawaya (1981), however this research uses two basis methods to adjust futures prices. Rather than focusing solely on margins from the cattle crush, the authors examine margins from other strategies, such as cash margins, never purchasing cattle, single commodity hedging, and using technical analysis to determine where hedges should be executed. Here again, target margin levels were outlined to determine whether a hedge was to be executed. It is discovered that live cattle hedging met the most target margins. While cattle crush hedging can be lucrative, less hedges were triggered due to margins that did not meet requirements.

Mean-variance analysis has also been beneficial to research that has sought to determine optimal hedge ratios. In other words, risk managers not only have to determine the optimal hedging strategy, but they must figure out whether they want to hedge their entire cash position or a smaller percentage. Parameters for risk aversion can be used to represent an individual's risk tolerance. These risk tolerance parameters are found to have a significant impact on a risk

manager's chosen hedging ratio. Rarely is it optimal to entirely hedge both inputs and the output when implementing the cattle crush (Peterson & Leuthold, 1987). These findings were expanded by Noussinov and Leuthold (1999) as they set out to identify an optimal hedging strategy while incorporating hedging ratios. The problem was set up as such that profits would be maximized, like work done by Fackler and McNew (1993) for soybean crushers. Profit functions were then used to develop equations. These equations were regressed to estimate optimal hedge ratios. Ratios were then used to determine cattle feeding margins from each risk management strategy. The strategies evaluated include unique variations of multiproduct hedging, single commodity hedging, and not hedging at all. Mean-variance analyses is then used to compare margins. This research only offers each turn of cattle one hedging opportunity. In other words, hedging strategies were automatically executed one month ahead of making feeder cattle purchases, regardless of whether the market was offering a positive or negative margin. In terms of hedge ratios this research is consistent with the results of Peterson & Leuthold (1987). However, if single commodity hedging is implemented the optimal hedge ratio is around one. The research does not conclude that any hedging strategy is necessarily superior. Instead, it is determined that engaging in any form of hedging strategy is more lucrative to risk managers than avoiding hedging all together (Noussinov & Leuthold, 1999).

Finally, cattle feeding margins from 1972-1976 were analyzed in Leuthold and Mokler (1978). The authors' primary objective was similar to the goals within this research in that they wanted to evaluate margins the commodity futures market offered, and if futures markets were useful as a part of a risk management strategy. Expected margin evaluation from cattle crush hedging started three months prior to the purchase of feeder cattle. After cattle were placed, expected margins continued to be examined using single commodity hedging, and once live

cattle were marketed, a cash margin was generated. Profit margin equations were developed and modified as cash positions were taken. Like other research, hedges were only executed if explicit margin targets were met. The initial target started at a profit of \$1 per hundred weight and increased by \$1 increments. They find that as the required margin target climbed higher, less hedges are triggered. The market offered a profitable margin at some point on each of the 234 turns of cattle examined. It is concluded that use of the commodity futures markets to evaluate and potentially secure optimal margins is a worthwhile practice for cattle feeders.

2.5 Contributions to Literature

Though previous research has been done analyzing margins in cattle feeding, this research provides an update to what has been done in the past. The dynamics of the industry and prices have shifted since the completion of previous studies. This research uses more current pricing information that was discovered under current conditions in the industry. Also, most research done, has spanned short stretches of time. This research involves about ten years of data generated by the cattle feeding sector. Which allows for margins to be studied through periods when different fundamental factors were at play. Much of the previous literature that has examined cattle feeding margins has made assumptions pertaining to corn needs and costs. While this approach is functional, costs of cattle feeding can be more accurately represented with actual feedlot data. This research makes use of actual and projected costs of gain reported by feed lots in margin calculations. Actual costs of gain are also used to construct a model to forecast expenses that have yet to be incurred. This allows both expected and actual margin results produced by this research to represent more closely what was observed by cattle feeders.

CHAPTER 3: DATA

Data from several sources was compiled to construct cattle feeding margins. Commodity futures prices for live cattle, feeder cattle, and corn were obtained on a weekly basis from the CME. For consistency, the closing price on the final trading day of each week was used in all equations where a futures price was required. Use of closing futures prices is consistent with both Schroeder and Hayenga (1988) as well as Leuthold and Mokler (1978). Live cattle prices and actual weights were derived from the Five Area Weekly Weighted Average Direct Slaughter Cattle report. This report is published by the United States Department of Agriculture – Agricultural Marketing Service (USDA-AMS). What makes this report ideal for this research is the summarization of negotiated trade that occurred in the primary U.S. cattle feeding region. The focus of this research was on steers sold on a Live-FOB (freight on board) basis, grading 65-80 percent choice. Margins calculated are for cattle sold on a live weight basis, no dressed prices were used. These parameters were set to capture most cattle marketed over the course of the study period. Feeder cattle weights and prices were sourced from the Feeder Cattle Index, published by the CME. The index price is a seven-day average calculated by compiling reported cash transactions, in the 12 states where feeder cattle are predominately traded. This data is optimal for calculating margins on a national basis, rather than using regional sale barn prices. Only steers of domestic origin that abide by specific specifications for muscle and frame can be used in index calculations. Dairy, exotic, and brahman-influenced feeder cattle are barred from the index (CME Group, 2019). Cattle represented by both the CME Index and the Five Area Weekly Weighted Average Direct Slaughter Cattle report align quite closely.

To calculate more representative margins, feedlot production data is needed to inform the costs associated with finishing cattle. Production data for this research was obtained from the *Focus on Feedlots* dataset, published by the Animal Sciences and Industry Department at Kansas State University. Closeout data is aggregated and reported monthly from participating feedlots. This dataset is meant to depict cattle performance and costs while in a feedlot. This data includes information for both steers and heifers, for this research heifers were filtered out. Variables reported include days on feed, purchase weights, marketing weights, and average daily gain. However, the variables of interest to this research include cost of gain (COG) and the projected cost of gain (PCOG). COG illustrates the costs incurred by cattle currently being marketed. PCOG projects costs to be incurred by cattle that are being placed during the month the report is published. Both figures include costs such as feed, yardage, processing, veterinary medicine, and death loss. Cost calculations account for cattle that are sold on a FOB basis with a four percent pencil shrink. One of the shortcomings of both COG is and PCOG is the inclusion of yardage. This may have inflated costs in margin equations and resulting margins may have underestimated what was observed in practice. Summary statistics of raw prices and production data are included in Table 1.

Table 1: Production and Price Data Summary Statistics

Statistic	Mean	Standard Deviation	Min	Percentile (25)	Percentile (75)	Max
Focus on Feedlots:						
Days on Feed	162.757	14.913	131.000	152.000	170.000	206.000
Cattle In Weight	797.061	36.433	690.000	773.000	828.000	870.000
Cattle Out Weight	1393.983	40.547	1286.000	1366.000	1423.000	1478.000
Average Daily Gain	3.614	0.185	3.130	3.470	3.760	4.000
COG	89.090	15.373	66.700	77.600	96.520	133.720
PCOG	87.911	16.098	66.250	75.500	97.000	129.330
CME:						
Feeder Cattle	152.008	27.481	96.350	137.000	158.725	240.975
Corn	4.638	1.103	3.180	3.880	5.320	8.120
Live Cattle	121.442	15.261	87.325	111.450	130.925	170.425
Feeder Cattle Index	151.027	30.667	94.652	134.336	156.327	242.792
USDA:						
5 Area Price Averag	123.172	17.065	90.940	111.740	128.110	171.600

Source: Focus on Feedlots; USDA AMS; Chicago Mercantile Exchange

CHAPTER 4: METHODS

The methods used to derive historical actual and expected margins are outlined in this chapter. The opening section sets the stage discussing the production setting and identifying parameters used in this research. Section 4.2 covers the process used to determine actual margins discovered in the cash market. Basis calculations needed to adjust commodity futures prices are defined in Section 4.3. Live cattle hedging expected margin construction is the primary topic of the subsequent section. Section 4.5 develops the cost of gain model used in crush hedging margin equations. Finally, in section 4.6 the procedures used to configure expected margins from cattle crush hedging are detailed.

4.1 Production Setting

This research will use a hypothetical cattle feeding scenario located in the primary U.S. cattle feeding region. In doing so, margin results will reflect what occurred on a national basis rather than a specific region or state. This allows derived results and conclusions to be more applicable to a wider audience of cattle feeders. This operation feeds beef steers of domestic origin, which will be sold to a U.S. beef processor at the conclusion of the feeding period. Heifers and dairy cattle were excluded from this analysis as beef steers make up most cattle on feed. Prior to purchasing feeder cattle, cattle will come into the feedlot weighing 800 lbs. Once feeder cattle have been purchased, actual weights will be used. Similarly, in advance of marketing cattle, live cattle are expected to weigh 1390 lbs. After marketing, actual live cattle weights will be used.

Feeder cattle are purchased once weekly throughout the study period. January 1, 2010 is the initial purchase date, and the last pen of cattle is procured on December 18, 2020. Cattle are purchased and placed simultaneously. Previous literature where cattle feeding scenarios were constructed made days on feed assumptions that ranged from 120 to 182 days (Noussinov & Leuthold, 1999; Hayenga et al., 1984; Leuthold & Mokler, 1978). The cattle feeding scenario in this research sets the on-feed time at 161 days or 23 weeks. This feeding period is based closely on the average days on feed (DOF) from the Focus on Feedlots production dataset. Live cattle are marketed on the final day of the feeding period, with the initial marketing date being June 11, 2010, and a final marketing date of May 28, 2021. Live cattle will also be marketed on a once weekly basis. Cattle are always purchased and marketed on Fridays, or the final business day of the week. If Friday happened to be a holiday, then the preceding Thursday was used as the purchasing or marketing date. Across the ten years examined in this research, there are 573 turns of cattle. Cattle that are purchased, fed for the prescribed feeding period, and finally marketed would equate to one turn of cattle. Each of these turns of cattle make up one base observation.

Starting one year prior to the intended marketing date, each of the 573 base observations has 52 margin opportunities. All but one of the 52 margins will be secured through one of the two hedging strategies used in this research. Margins garnered through hedging are also known as expected margins. Of the 51 expected margins, 28 are from cattle crush hedging. The remaining 23 margins are generated from live cattle hedging. For each base observation, there is a specific period in which a respective strategy can be executed. These periods are keyed off both the purchase and marketing date of base observations. In the final week of the one-year period, the last of the 52 margins is produced. This is a cash or an actual margin, which is determined only after cash prices of all commodities become realized. All margins are evaluated

on a dollars per head basis. Margins are determined once weekly, on the final business day of each week. Like before if Friday was a holiday, then Thursday's margin would be used.

4.2 Cash Margins

With each base observation acquiring one cash margin, this results in 573 cash margins evaluated in this research. These margins are indicative of what a cattle feeder's margin would be without engaging in any hedging strategies. While a cattle feeder can make the choice of whether to hedge, if they are going to feed cattle, a cash margin is always generated.

To calculate historical actual margins a cash margins matrix was constructed. Actual vectors of weights and prices from the Feeder Cattle Index and the Five Area Direct Slaughter Cattle report were merged to build this matrix. This data was joined using the date of the Feeder Cattle Index as the placement date. Placement dates would then be matched with a trade date from the Direct Slaughter Cattle report. It is important to note that the Five Area Direct Slaughter Cattle report is published on Mondays summarizing cash live cattle trade that occurred in the prior week. As a result, using the report release date would have misaligned weights and prices within the matrix. To remedy this issue the Friday prior to the release date was used as the trade or marketing date. This date could then be matched with a placement date that was 161 days prior. To complete the cash margins matrix, vectors from the production dataset were added. To interjoin monthly production data with the weekly cash matrix, respective months and years were extracted from marketing dates. Datasets were then joined by matching respective months and years.

Margin equations take the same general form as any profit equation, where expenses are subtracted from revenues. The equation to calculate cash margins can be characterized as:

$$Margin_{hd} = \left[\left(\frac{LE.cash}{100} \right) * out.weight \right] - \left[\left(\frac{FCI}{100} \right) * in.weight \right] - TCOG$$

Equation 1: Cash Margins

The first term on the right-hand side of the equation is the actual revenue made from marketing live cattle. The following two terms subtracted are representative of actual costs. *LE.cash* is the cash price received for live cattle upon marketing, while *FCI* is the feeder cattle index price, or the cash price paid to purchase feeder cattle. Both prices are reported in dollars per hundredweight. Dividing each price by 100 is necessary to set prices on a dollars per pound basis. Next, both prices are multiplied by respective weights. *out.weight* is the actual live weight of cattle when marketed and *in.weight* is the actual weight of feeder cattle at the time of purchase. Use of actual weights allows this study to be representative of cattle entering and exiting feedlots over the study period. After prices had been multiplied by weights, the first two terms in the equation are both on a dollars per head basis.

TCOG or total cost of gain is the final term in Equation 1. The Kansas State production dataset reports a closeout COG on a dollars per hundredweight basis. To derive *TCOG* from the reported figure the following equation is used:

$$TCOG = \left[\frac{out.weight - in.weight}{100} \right] * COG$$

Equation 2: Total Cost of Gain

Subtracting the weight of feeder cattle at placement, from the weight of live cattle at marketing gives the total amount of actual weight gained during the feeding period. To get both terms on the right-hand side of the equation in similar units, cattle weight gain is divided by 100. At this point, *TCOG* is in per head units.

4.3 Commodity Basis

Expected margins are determined without knowing all the actual cash prices that will be paid or received. The placeholder of cash prices that have yet to be determined are forward prices. These prices consist of basis-adjusted futures prices. Rather than using futures prices alone, forward prices are meant to align closer with cash prices at the time physical transactions are made. Basis is the difference between commodity futures and cash prices. Futures and cash prices for any commodity are rarely ever the same. In theory, the two price sets should converge as each respective commodity futures contract nears expiration (Purcell & Koontz, 1999). Actual basis illustrates the true difference that occurred between commodity futures, *com.fut*, and cash markets, *com.cash*, at the time cash transactions took place:

$$basis.act = com.cash - com.fut$$

Equation 3: Actual Basis

Weekly basis was determined using futures and cash data from sources outlined previously, going back to January 2004. In practice, it would not be possible to know the actual basis incurred prior to purchasing or marketing cattle. But, in this research, it serves as a useful study to examine how margins vary when prices are adjusted by actual basis versus expected basis.

Ahead of executing cash transactions, a cattle feeder would only know an expected basis, or an estimate of what basis may be. Basis is difficult to forecast as it is affected by numerous fundamental market factors. Historical averages are one way to formulate an idea of the actual basis that will be incurred. Three different historical averages were used in determining an expected basis, a three-year simple average, five-year simple average, and five-year trimmed average. Expected margins from both hedging strategies were calculated with all three averages.

However, the three-year average was most correlated with the actual basis for both feeder cattle and live cattle. For brevity, only the three-year rolling average is presented here and in expected margin calculations in subsequent sections:

$$basis.3yr = avg(basis.act_{-1}, basis.act_{-2}, basis.act_{-3})$$

Equation 4: Expected Basis

The five-year simple average and five-year trimmed average basis estimating equations are illustrated in Appendix B. Once vectors of actual and expected basis were constructed for both feeder cattle and live cattle, they were joined with corresponding base observations. Feeder cattle basis dates were merged with placement dates and live cattle basis dates joined with marketing dates.

4.4 Live Cattle Hedging Returns

Prior to cash margin discovery, while cattle are on feed, a cattle feeder can secure margin using single commodity hedging in the live cattle market. For this research, the opportunity to engage in live cattle hedging is clearly defined as the period that starts once cattle are purchased and ends one week prior to the intended marketing date. This allows for 23 margin opportunities evaluated over the feeding period. When evaluating margins from live cattle hedging, prices of inputs have been realized, and only the output price remains variable.

To engage in this form of hedging, a cattle feeder must select which of the six live cattle contracts they would like to hedge cattle against. Typically, contracts are chosen to be nearest the intended cattle marketing date but have not expired. For example, if a projected marketing date were July 10, 2015, one would hedge this animal against the August live cattle contract. Though the June live cattle may be closer in a count of calendar days, this contract expires prior to the

marketing date in early July. Each of the 573 base observations was assigned a nearby live cattle contract under which they would be hedged following this construct. It is presumed that a hedge executed is held for the remainder of the feeding period. Once cattle are marketed then the position is exited through offsetting trades. In this research, hedges were always offset, meaning physical delivery was not considered.

Like the steps taken to assess cash margins, a data matrix was built to evaluate expected margins from live cattle hedging. Vectors of placement dates, marketing dates, live cattle actual basis, live cattle expected basis, and actual feeder cattle weights and prices were subset from the base data. Base observations were duplicated 23 times, to represent all live cattle hedging margin opportunities that occurred during a feeding period. Each of the 23 rows was given a number one through 23 to indicate the hedge week, one being the final week live cattle hedges could be placed and 23 being the first. Based on the hedge week and the base observation's marketing date, rows were then assigned a hedge execution date. These were the final business day of each week throughout the feeding period. ISO weeks and ISO years were extracted from hedge execution dates. Both ISO weeks and ISO years originate from a week numbering convention that uses the ISO 8601 calendar structure. Rather than counting weeks and assigning week numbers, this process better accounts for the inherent unevenness that is present in the Gregorian calendar. This unevenness revolves around the fact that years rarely begin on a Monday and end on a Sunday (The ISO 8601 Calendar, n.d.). A vector of live cattle futures closing prices were then merged into the live cattle hedging matrix. To do so, ISO weeks and ISO years were extracted from each commodity futures entry date. Both datasets could then be joined on matching ISO weeks and years as well as the futures contract month that matched the nearby contract month specified for each base observation. Lastly, costs from the production data were

added to the live cattle hedging matrix. Like before, production data was joined based on matching months and years. However, it is important reiterate, Focus on Feedlots monthly data reports PCOG for cattle placed the month the report was issued. Whereas remaining variables in the dataset are for cattle being marketed in the month of the report. Thus, production data was joined with the live cattle hedging matrix based on corresponding placement dates rather than marketing dates.

Before expected margins from live cattle hedging could be generated, futures were basis adjusted to determine the forward price that would go into the expected revenue side of live cattle hedging margin equations.

$$\begin{bmatrix} LE_{fp}basis.act \\ LE_{fp}basis.3yr \end{bmatrix} = LE_{fut} + \begin{bmatrix} LEbasis.act \\ LEbasis.3yr \end{bmatrix}$$

Equation 5: Live Cattle Forward Prices

Both actual live cattle basis, $LEbasis.act$, and expected live cattle basis, $LEbasis.3yr$, were used to correct live cattle futures prices, LE_{fut} , yielding two vectors of forward prices, $LE_{fp}basis.act$ and $LE_{fp}basis.3yr$. The equation for expected margins from live cattle hedging can now be defined as:

$$\begin{bmatrix} hg.Margin_{act} \\ hg.Margin_{3yr} \end{bmatrix} = \begin{bmatrix} [LE_{fp}basis.act/100] \\ [LE_{fp}basis.3yr/100] \end{bmatrix} * exp.out - \left[\left(\frac{FCI}{100} \right) * In.weight \right] - PTCOG$$

Equation 6: Live Cattle Hedging Expected Margins

Expected margins calculated with actual basis are represented by $hg. Margin_{act}$, while $hg. Margin_{3yr}$ are expected margins determined with expected basis. The first term in Equation 6 now represents expected revenue from marketing live cattle. To do so, forward prices are converted to dollars per pound and multiplied by the expected weight of live cattle at marketing, $exp. out$. The second term in the equation, representative of actual feeder cattle expenses is unchanged from Equation 1. Finally, $PTCOG$, projected total cost of gain, is subtracted. The equation for $PTCOG$ is like Equation 2:

$$PTCOG = \left[\frac{exp. out - in. weight}{100} \right] * PCOG$$

Equation 7: Projected Total Cost of Gain

Similar to COG, Focus on Feedlots reports $PCOG$ on a dollars per hundredweight basis. Actual placement weights, $in. weight$, are subtracted from expected marketing weights, $exp. out$, to determine projected weight gain. This weight gain is then put on a hundred weight basis and multiplied by $PCOG$. The result is, $PTCOG$ on a dollars per head basis.

4.5 Modeling Cost of Gain

A COG model is developed to forecast costs to be incurred through the feeding period, well in advance of the placement month. Forecasted costs are then used to determine expected margins from cattle crush hedging. The model will allow for seasonal and inter-year differences in COG to be expressed. Corn makes up a considerable proportion of rations used by cattle feeders. As a result, COG is strongly correlated with the price of corn, making it a major determinant of the costs of finishing cattle. For model estimation, corn spot futures prices were aggregated into a monthly average. This was done so that monthly average spot futures prices could be joined with the vector of monthly COG variables from the production data. Marketing

months were merged with matching months from the spot corn price data. After data had been aligned corn prices were lagged by three months. This is to accommodate the construct of the cattle crush, where the corn contract used sits about in the middle of the feeding period. Within this research, three months prior to the marketing date would be about the midpoint of the 23 week on-feed period.

Two COG models were developed, however only one is specified here. The alternate model is presented in Appendix A. The primary model is such that:

$$\begin{aligned}
 ECOG = & \alpha + \beta_1 \ln(ZC_{-3}) + \beta_2 trend + \beta_3 Feb + \beta_4 Mar + \beta_5 Apr + \beta_6 May \\
 & + \beta_7 Jun + \beta_8 Jul + \beta_9 Aug + \beta_{10} Sep + \beta_{11} Oct + \beta_{12} Nov \\
 & + \beta_{13} Dec + u_t
 \end{aligned}$$

Equation 8: Estimated Cost of Gain Model

ECOG, or the estimated cost of gain, is the dependent variable of the model. α is the intercept coefficient. The first independent variable following the intercept is the natural log of the three-month lagged corn price. Remaining independent variables include a trend variable to represent COG differences across years and monthly seasonal variables to encompass intra-year differences. The trend variables are a vector of numbers from 1 to 149 assigned to each monthly observation of corn futures prices and COG. Monthly seasonal variables are binary and used to indicate the cattle marketing month. To avoid the dummy variable trap, the month of January is used as the benchmark, thus the binary variable for that month was omitted (Gujarati & Porter 2009). Finally, u_t is included to capture the residual within the model. To estimate this model and obtain coefficients, the OLS method of linear regression was used.

4.6 Cattle Crush Hedging Margins

Cattle crush hedging is the final way in which margins are examined in this research. This strategy allows cattle feeders to secure a margin well in advance of physically purchasing feeder cattle. This interval of time, known as the crush period, provides the first look at potential margins that a producer could expect at some point in the future. This period is initiated one year prior to the intended live cattle marketing date and ends one week prior to cattle being purchased. In all actuality, crush margin evaluation could start earlier. However, using the start date specified by this research ensures there will be adequate liquidity in each of the involved commodity futures contracts. Thus, a cattle feeder could realistically execute the crush hedging strategy without running into issues associated with low trade volume. It is important to note, that once a cattle feeder executes a cattle crush hedge, these positions are maintained and only offset once a position is taken in each respective physical market.

As was previously stated the cattle crush involves the simultaneous hedging of specific futures contracts from the feeder cattle, corn, and live cattle complexes. Each commodity complex has individual futures contracts which are traded in particular months. Feeder cattle contracts are traded in eight months out of the year, corn in five months, and live cattle in six months. There are a number of different aggregations that can form a crush however, nine were selected to be used in this study and are shown in Table 2.

Each of the original 573 base observations was assigned one of the nine selected crushes based on the parameters that neither the feeder cattle contract nor live cattle contract was expired before the pen was purchased or shipped, respectively. If either contract were expired before a cash position was taken, the observation would be matched with the next successive cattle crush.

Table 2: Cattle Crushes

	Feeder Cattle Futures Contract	Corn Futures Contract	Live Cattle Futures Contract	Code
Crush #1	January (GFF)	May (ZCK)	June (LEM)	FKM
Crush #2	March (GFH)	July (ZCN)	August (LEQ)	HNQ
Crush #3	April (GFJ)	July (ZCN)	October (LEV)	JNV
Crush #4	May (GFK)	July (ZCN)	October (LEV)	KNV
Crush #5	August (GFQ)	December (ZCZ)	December (LEZ)	QZZ
Crush #6	August (GFQ)	December (ZCZ)	February (LEG)	QZG
Crush #7	September (GFU)	December (ZCZ)	February (LEG)	UZG
Crush #8	October (GFV)	March (ZCH)	April (LEJ)	VHJ
Crush #9	November (GFX)	March (ZCH)	April (LEJ)	XHJ

This method of assigning specific crushes has been implemented by prior research (Noussinov & Leuthold, 1999).

Selecting which corn contract to be used in each respective crush was a less exact process. Corn contracts were chosen to be between feeder and live cattle contracts. Though this process of assigning corn contracts does not work out perfectly. The major exception is crush five (QZZ) where both corn and live cattle are being hedged in the December contract. While use of the September contract would have been more in line with the process outlined above, it may have negatively affected resulting margins. The reason for this is that within the corn complex, September is the last contract where old crop corn is traded, which can cause volatility depending how much supply of old crop corn remains. The December corn futures contract is where new crop corn is first traded, coinciding with U.S. corn harvest. If there is remaining old crop corn, by the time September becomes the nearby corn contract, much of the trading volume has already shifted into the December contract. All this considered, September corn futures were not factored into selected crushes.

Once again, variables were subset from the base dataset to build out the cattle crush hedging data matrix. Necessary vectors included placement dates, marketing dates, actual and expected basis for both feeder as well as live cattle, and finally the individual crush that had been assigned to each observation. Individual rows for each observation were replicated 28 times and assigned a number that corresponded to a crush hedging week, similarly to how live cattle hedging weeks were assigned. Crush week numbers would be used to determine the final business day of each week that would be used as the crush hedge execution date. From these dates, ISO week and year variables were rendered. Futures data was then needed to complete the crush hedging matrix, but rather than join each futures price individually, a crush futures dataset was compiled. Feeder cattle, corn and live cattle futures prices were joined based on contract months that aligned with one of the nine specific crushes and matching entry dates. ISO weeks and years were given to each entry date in the futures data. Vectors from the cattle crush hedging matrix could then be joined with crush futures data by matching cattle crushes as well as ISO weeks and years.

Forward prices for both live and feeder cattle are required in the cattle crush margin equations. Live cattle futures prices were again basis adjusted using Equation 5. Feeder cattle prices are basis adjusted to form forward prices using a similar process.

$$\begin{bmatrix} GF_{fp}basis.act \\ GF_{fp}basis.3yr \end{bmatrix} = GF_{fut} + \begin{bmatrix} GFbasis.act \\ GFbasis.3yr \end{bmatrix}$$

Equation 9: Feeder Cattle Forward Prices

Two vectors of forward prices, $GF_{fp}basis.act$ and $GF_{fp}basis.3yr$ are the result of adding both actual feeder cattle basis, $GFbasis.act$, and expected feeder cattle basis, $GFbasis.3yr$, to futures prices of feeder cattle, GF_{fut} .

Corn futures prices were directly input into the cost of gain model developed in the prior section. Once *ECOG* was determined for each observation in the crush hedging matrix then the estimated total cost gain, *ETCOG*, could be calculated using:

$$ETCOG = \left[\frac{exp.out - exp.in}{100} \right] * ECOG$$

Equation 10: Estimated Total Cost of Gain

Where neither the placement nor the marketing weigh is yet known, expected weights are used, *exp.in* and *exp.out*. The difference of the expected weights is taken and then divided by one to determine the expected hundredweights gained. The expected hundredweights gained is then multiplied by *ECOG* resulting in *ETCOG*, on a per head basis.

Expected margins from cattle crush hedging are determined once weekly using a variation of the profit equation used in previous margin calculations. While Equations 6 and 11 share the term illustrating expected revenue from marketing live cattle, both cost terms have changed. The equation for cattle crush hedging margins is presented as:

$$\begin{aligned} & \left[\begin{array}{l} cr. Margin_{act} \\ cr. Margin_{3yr} \end{array} \right] \\ & = \left[\begin{array}{l} LE_{fp} basis. act / 100 \\ LE_{fp} basis. 3yr / 100 \end{array} \right] * exp.out \\ & - \left[\begin{array}{l} GF_{fp} basis. act / 100 \\ GF_{fp} basis. 3yr / 100 \end{array} \right] * exp.in \right] - ETCOG \end{aligned}$$

Equation 11: Cattle Crush Hedging Expected Margins

To calculate expected feeder cattle costs, feeder cattle forward prices are put on a dollars per pound basis and multiplied by the expected placement weights, *exp.in*. Expected feeder cattle

costs can then be subtracted from expected revenues from live cattle. Lastly, *ETCOG* is subtracted to generate two vectors of cattle crush hedging margin results on a per head basis. The first expected margin, *cr. Margin_{act}* uses the feeder and live cattle forward price adjusted by actual basis. While the second, *cr. Margin_{3yr}*, employs the forward price figured with the three-year average estimate of basis.

CHAPTER 5: DISCUSSION AND RESULTS

To this point, sections have provided rationale and outlined the way in which this research was conducted. This chapter lays out results and delivers discussion pertaining to the outcomes of this research. In section 5.1 margin strategies are compared on a number of levels. The next section evaluates each strategy on a more individual basis. Section 5.3 looks at how marketing strategies performed under various market fundamentals that occurred during the examination period. Lastly, section 5.4 examines results from the cost of gain model.

5.1 Margin Strategy Comparison

Resulting cattle feeding margins were calculated with either actual or expected basis methods. Over the course of this and subsequent sections, results will sometimes be presented using both basis methods and other times only one method will be illustrated for conciseness. It will be made clear what margin or margins are being presented and discussed. As outlined in the methods section, expected basis results will only be from the three-year rolling average method of approximation. Cattle Crush hedging margins were calculated using costs from the *ECOG* model as presented in the previous chapter. An overview of margin results produced by the alternate COG model are presented in Appendix C. This analysis Starts with an overview of margin results determined throughout the study period. To do so summary statistics of margins results are presented first, in Table 3.

Table 3: Margin Summary Statistics by Category (per head)

Strategy:	Mean	Standard Deviation	Min	25 Percentile	75 Percentile	Max
Cash	2.978	162.745	-573.378	-93.220	98.751	485.854
Live Cattle Hedging (Actual Basis)	-3.512	137.291	-682.506	-87.707	80.318	509.870
Live Cattle Hedging (Estimated Basis)	-8.544	126.223	-629.267	-87.607	71.652	468.882
Crush Hedging (Actual Basis)	-47.603	72.354	-301.053	-89.086	-9.398	344.888
Crush Hedging (Estimated Basis)	-52.571	44.438	-211.547	-79.845	-25.078	178.877

Only one vector of cash margins is produced, as these margins do not require any basis adjustments. Thus, only one set of summary statistics is yielded in Table 3 from this strategy. While hedging strategies each had two vectors of expected margin results. One vector was calculated with actual basis and the other with expected basis. Summary statistics for both hedging strategies, using both basis methods are also presented in Table 3. Starting with actual margins received in cash markets, the highest average is observed, slightly above zero at \$2.98 per head. Compared to previous research of Schroeder and Hayenga (1988), average cash margins have shifted lower. However, standard deviation has increased, by over \$100 per head.

Evaluating both vectors of expected margins from live cattle hedging, both averages were below zero. Relative to cash margins live cattle hedging shifts the mean between \$6 and \$11 per head lower. However, live cattle hedging margins calculated with both actual and expected basis reduced standard deviation by 15 and 22 percent, respectively. Both vectors of expected margins from cattle crush hedging exhibit the lowest average margin. Between cash and cattle crush hedging average margins there is over \$50 per head difference regardless of the basis method. The cattle crush hedging strategy offers the lowest standard deviation. Compared to cash, cattle crush hedging reduces standard deviation by over half.

Also, in Table 3 it is important to note the differences between margins calculated with actual basis and expected basis. For both live cattle hedging and cattle crush hedging, margins determined using actual basis exhibited higher averages and standard deviations. Between vectors of live cattle hedging results there is a \$5 per head difference in means and \$11 per head between standard deviations. Cattle crush hedging was like live cattle hedging in that there was a difference of \$5 per head between both vectors of margin results. Standard deviation increased by about \$28 per head from expected basis to actual basis cattle crush margins.

Mean variance analysis can help provide insight into the strengths and weaknesses of each margin strategy. For a cattle feeder, these differences are important to take into consideration when deciding whether to hedge, and if so, what strategy should be considered. As shown in Figure 2, cash margins have an average of greater than zero, which is positive for cattle feeders. Cash margins are imminent if a producer chooses to physically engage in cattle feeding.

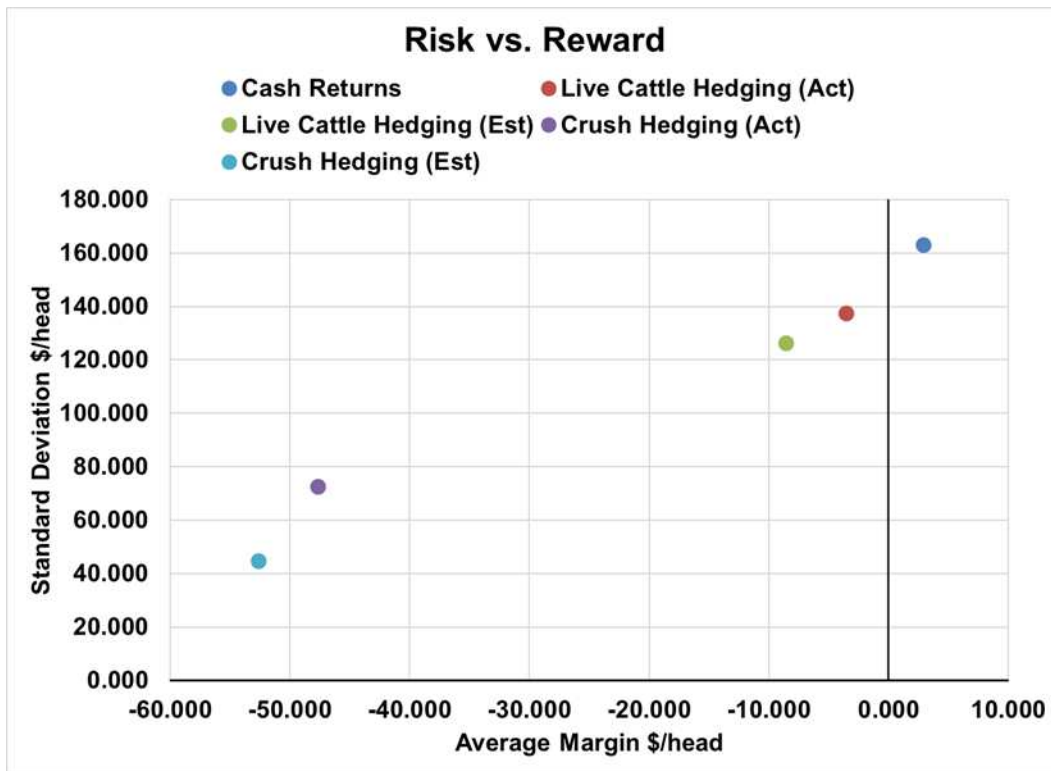


Figure 2: Mean and Standard Deviation by Margin Strategy

This margin heavily depends on what the cash market is offering at the time physical transactions occur. Though it is important to note that in practice, cattle feeders can pull fed cattle forward or push them back in an attempt to garner more favorable cash market prices. However, this flexibility has limits, especially during times of elevated feed costs. Unfavorable to cattle feeders is cash margins have the most volatility and are the riskiest of any margin results. Price taking when cash transactions are executed can yield positive outcomes. However,

sole dependence on cash margins can be a high-risk decision. This level of risk may be detrimental to the financial well-being of a cattle feeding entity.

Figure 2 also illustrates that both hedging strategies are effective at reducing risk, as remaining points in the plot are positioned lower relative to cash margins. However, the cattle crush hedging strategy produced margins that were the least volatile. The downside to either hedging strategy are the negative means. There is minimal difference between cash and live cattle hedging margins, and margins are only slightly below zero. The much larger decline occurs when evaluating cattle crush hedging margin means. Though, one must be cautious drawing conclusions on either hedging strategy based solely off negative average margins. There exist periods when hedging strategies can be used to secure improved margins compared to what was offered in the cash market. Either strategy provides a higher volume of margin opportunities for each turn of cattle compared to a single opportunity in the cash market.

Hedging strategies are typically executed with intentions of limiting price risk. The tradeoff for reducing price risk, is that once hedges are implemented, a cattle feeder must then be concerned with basis risk. Basis risk occurs when the spread between cash and futures at the time physical transactions are made, is significantly wider or narrower than what was expected. This tradeoff between price risk and basis risk is illustrated within Figure 2. Expected margins from either hedging strategy determined with actual basis were riskier than the same margins determined with expected basis. It is important to note, observed basis risk is significantly less than the risk exhibited by actual margins obtained in the cash market.

In Table 4, the percentage of positive and negative margins is compared between strategies. Differences between each margin strategy are similar those to differences observed when evaluating strategy means. Slightly less than half of cash margins were positive, as a larger

majority were negative. Live cattle hedging margins had the highest percent positivity rate regardless of the basis method examined. Margins from the cattle crush hedging strategy underperformed relative to both cash and live cattle hedging as about 80 percent or more were negative.

Table 4: All Margins Percent Positive vs. Percent Negative

Strategy:	% Positive	% Negative
Cash	48.17%	51.83%
Live Cattle Hedging (Actual Basis)	50.12%	49.88%
Live Cattle Hedging (Estimated Basis)	48.91%	51.09%
Crush Hedging (Actual Basis)	21.09%	78.91%
Crush Hedging (Estimated Basis)	11.45%	88.55%

Figure 3 outlines the distribution curve of each strategy's margin results calculated with actual basis. On the surface, most margins regardless of strategy fall in the -\$100 to \$100 per head range. A more in-depth analysis reveals that data components of each curve are normally distributed. The normal distribution requires a skewness coefficient that is between negative one and one. Cash margin data are positively skewed with a 0.062 coefficient. This is confirmed by the distribution curve as the positive tail extends furthest along the horizontal axis. Result data from crush hedging are more positively skewed with a greater coefficient. Live cattle hedging results is the only data that are negatively skewed. Though the skew is not extreme with a slight negative coefficient of -0.186 (Mackey, 2013).

Cattle Feeding Margins Actual Basis

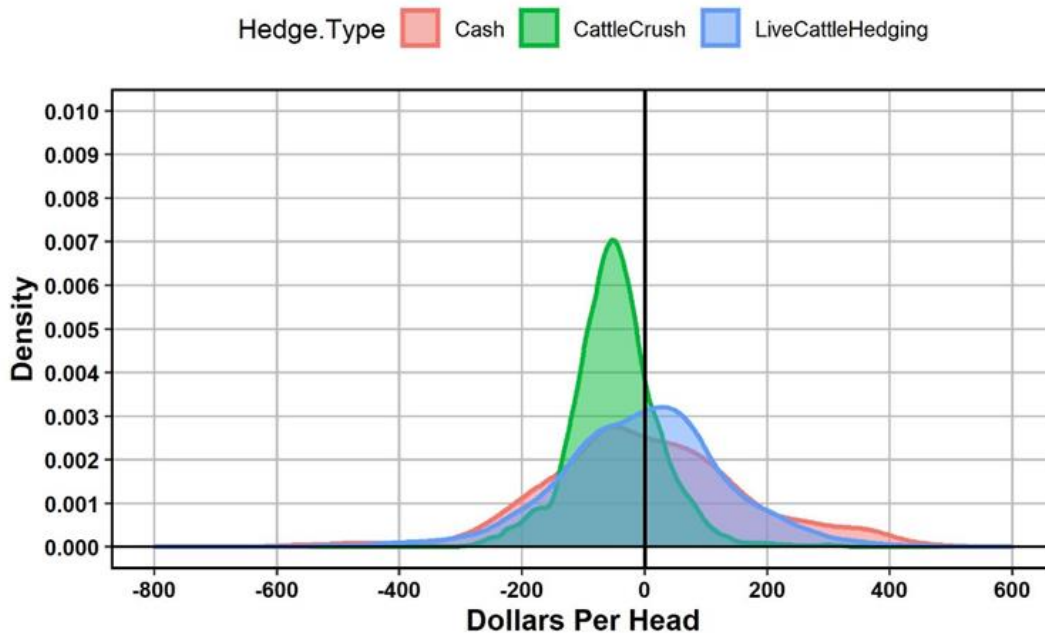


Figure 3: Distribution of expected and actual margins calculated with actual basis by strategy

Kurtosis examines the height and tails of a distribution curve. Each of the three result datasets are found to be leptokurtic. Curves of leptokurtic nature are typically found to exhibit one or each of two specific characteristics. The first is that curves are thin longitudinally. Second, curves have much longer tails, meaning that data are distributed over more space. Crush hedging's distribution curve exhibited the most positive kurtosis coefficient at 2.15, highlighted by the thinness of the curve and length of tails. Coefficients for live cattle hedging and cash margins were much lower at 0.934 and 0.683, respectively. Both curves are thicker in width, a quality of platykurtic curves. However, result data generated curves with elongated tails, still resulting in the leptokurtic determination (Gujarati & Porter, 2009).

Figure 4 illustrates the distribution curves of margins calculated using the expected basis method. The cash distribution is identical to Figure 3 as no basis adjusted futures prices are

required. All curve classifications of skewness and kurtosis remain the same across hedging strategy result sets. There are, however, a couple of differences to note. The first is that the crush hedging density curve is taller, an indication that margin data for this strategy are much more concentrated at the peak. Another difference to note is the peak of the live cattle hedging curve appears to shift slightly to the left, moving closer to the vertical axis, or a break-even margin.

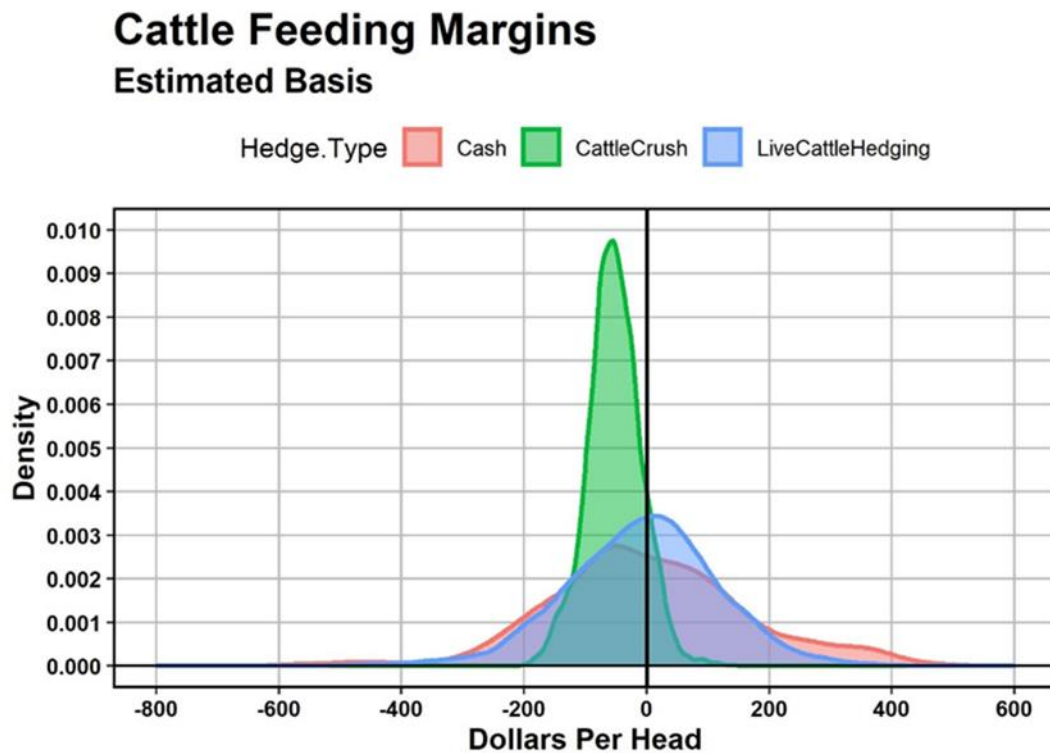


Figure 4: Distribution of expected and actual margins calculated with expected basis by strategy

Live cattle markets, whether cash or commodity futures, typically exhibit strong seasonal patterns. Prices climb to a high during the spring months of March through May. After highs are made, markets trend lower into the late summer months. Once lows have been established the market tends to move higher into the late fall and early winter. Through the remainder of the year into the start of the next, trade occurs at lower prices until the next spring rally occurs. Even though this pattern does not occur each year, it is exhibited more times than it is not. Seasonality

is driven by both supply and demand. Beef demand is typically strong going into summer months, as the weather changes, consumers begin to cook out or eat at restaurants. As a result, higher volumes of fed cattle are demanded by processors to keep pace with demand, pushing prices higher. A sizable number of live cattle are fed to be harvested during this time frame, as cattle feeders respond to demand and attempt to market cattle in higher price environments. The price highs in the latter part of the year can be explained by consumers boosting demand for holiday gatherings. Again, an elevated level of fed cattle is needed to meet this demand. Low prices in the late summer months can be explained by demand reductions as the grilling season ends (Davis et al., n.d.). This seasonality in prices is exhibited in Figure 5, where spot live cattle futures prices are charted for each year in the study period.

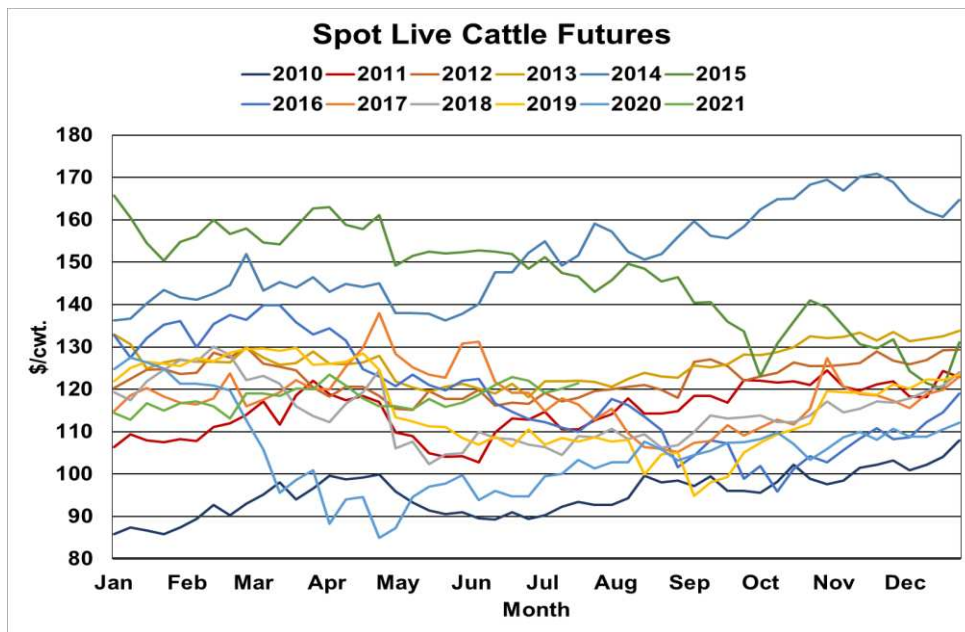


Figure 5: Spot live cattle futures for each year within the study period.

Average monthly margins offered by each strategy are illustrated in Figure 6. In other words, individual margins offered by each strategy were grouped together by the base observation's intended marketing month and were then averaged. The seasonal pattern described

for live cattle prices is also very apparent in average margins offered on an intra-year basis. Each vector of monthly average margins reaches an annual high in the spring, then margins break into an annual low sometime during the late summer and early fall. Margins then catch an uptrend until fall highs are established in November. The nearly identical seasonal patterns between live cattle prices and margins in cattle feeding do not come with much surprise as live cattle prices drive margins. However, this information does have value to those managing risk in the cattle feeding sector. Cattle feeders can use seasonal patterns to help better inform risk management decisions based on the time of year cattle are to be marketed. Looking more closely at each

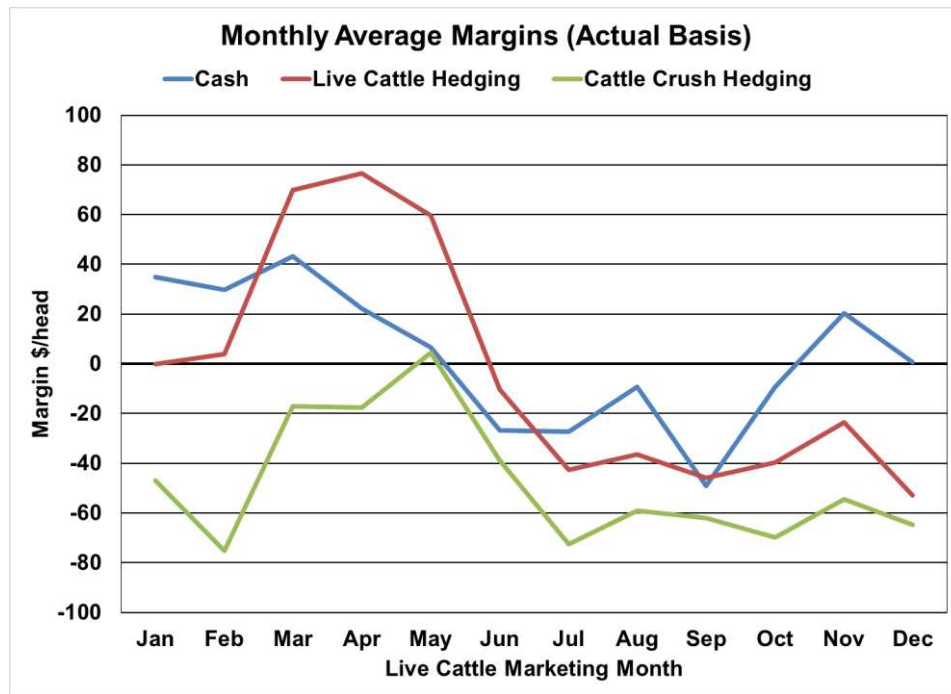


Figure 6: Margins calculated with actual basis, averaged by marketing month, presented on an intra-year basis.

strategy's average margin in Figure 6, cash performs the best of any strategy in January and February. During the springtime, live cattle hedging margins exhibited the highest average

between \$60-\$80 per head. Cattle crush margins had only one month with a positive average. This occurred in May at \$4 per head. After late summer early fall lows were set, average cash margins were able to establish enough of an uptrend to turn back positive in the month of November.

Overtime, Figure 7 illustrates that each margin strategy trends together in similar directions, the major difference is the magnitude to which margin averages shift. Here again, the cash series exhibits the most volatility establishing the highest and lowest average margins. Cash margins climbed to highs of \$415 and \$485 per head for cattle to be marketed in October 2014 and May 2017, respectively. Conversely, cash margins collapsed for cattle to be shipped in December 2015, plummeting to over -\$550 per head. To a cattle feeder, when margins are elevated, the cash strategy can be an attractive option. Though it is critical to note, cash was consistently the poorest option during times of depressed margins. 14 months, from October 2014 to December 2015, was all the time that was needed for cash margins to decline 240 percent. While not limiting upside potential may be favorable, the cash strategy does not offer any protection against diminishing margins. This amount of risk is substantial for cattle feeders.

Opposite observations can be made as it pertains to average margins offered by the cattle crush hedging strategy in Figure 7. Cattle crush average margins established a minimum at the same time as cash margins, though the difference between them was the crush hedging average was \$326 per head greater. The maximum average available margin offered by cattle crush hedging was set for cattle marketed in April 2020 at \$300 per head. For the remainder of the study, average crush hedging margins for each base observation fluctuated between -\$100 and \$100 per head, further substantiating the strategy as the least volatile. To the risk managing cattle feeder, reduced volatility is an appealing trait of cattle crush hedging. Additionally, in

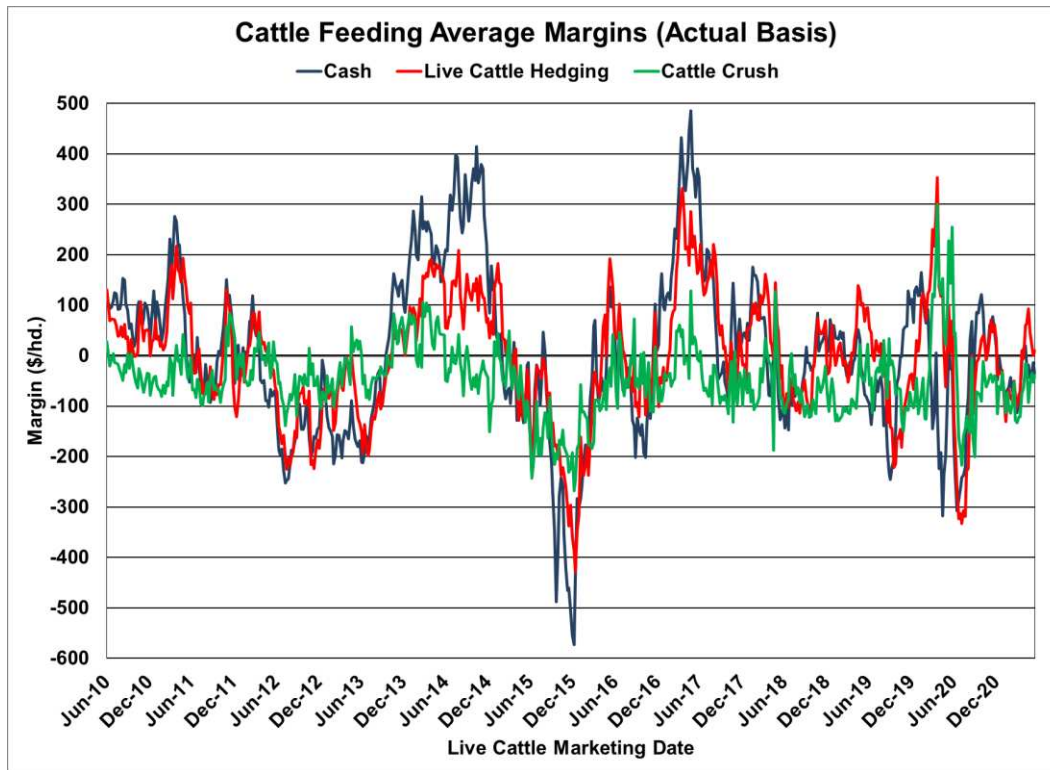


Figure 7: Average margin offered by each strategy for all base observations.

environments where margins are trending lower, implementing this strategy is effective in limiting the degree to which margins move lower. However, during periods of increasing margins upside potential is most limited by cattle crush hedging.

Live cattle hedging serves as the intermediate strategy between cash and cattle crush margins. Live cattle hedging average margins reached lows of -\$374 for the same marketing period when other strategy's average lows were made, this was still \$200 per head above what was offered in the cash market. The base observation that had the highest average crush margin also had the highest live cattle hedging average margin. However, it was \$50 per head larger than the average cattle crush hedging margin. Compared to cash margins, live cattle hedging provides more protection against decreasing margins, even though some upside potential is limited. But

when compared to cattle crush hedging, live cattle hedging shifts the mean higher during periods of increasing margins, although downside risk is greater when margins are trending lower.

5.2 Individual Strategy Evaluation

The focus of this discussion shifts from strategy comparison to an individual evaluation of each strategy. It is important to know the strengths and weaknesses of each strategy, not only in a comparative sense, but on an individualized basis as well. One aspect to consider is how a specific strategy performs over the course of a year. There are likely months when a strategy should be considered, and other times when strategies may underperform. Also, it is important for cattle feeders to have an idea of what level of margins they should seek given the strategy being entertained. Throughout this discussion, insight into these aspects will be provided. Ultimately, this should aid cattle feeders in their decision-making process and help them better understand what the commodity futures and cash markets are signaling.

5.2.1 Cattle Crush Hedging

Evaluating both Table 5 and Figure 8, a cattle feeder looking to engage in cattle crush hedging would be best to do so on cattle slated to be marketed in the springtime. First, looking at each month, averages for March, April, May, and June are the greatest, though May is the only month above zero. However, more motivating than the average is the fact that each of these months has margins in the 75th percentile that are positive, indicating that there were opportunities to secure profitable margin. This statement is confirmed in Figure 8 as the spring and early summer months have the most positive opportunities. Across these months 25 to 50 percent of calculated margin results were positive. To put this in context, the remaining eight months of the year had an average of 12.5 percent positive margins. Of these eight months,

Table 5: Cattle Crush Hedging Margins Summary Statistics by Projected Marketing Month

Crush Hedging Margins (Actual Basis/Per Head)

Marketing Month	Mean	Standard Deviation	Minimum	25th Percentile	75th Percentile	Maximum
January	-46.838	59.181	-214.899	-85.273	-21.140	118.683
February	-75.254	45.494	-222.040	-107.484	-42.505	53.170
March	-17.174	86.093	-236.406	-86.117	45.528	248.610
April	-17.475	82.187	-214.295	-65.431	7.155	344.888
May	4.576	71.749	-186.895	-46.529	42.710	300.896
June	-38.733	79.974	-299.474	-76.098	1.190	320.828
July	-72.503	65.947	-263.038	-106.815	-22.858	116.615
August	-58.985	49.533	-219.432	-90.130	-26.955	117.878
September	-62.022	61.795	-268.146	-92.002	-23.097	121.729
October	-69.887	51.239	-263.963	-90.926	-37.022	53.506
November	-54.360	72.335	-284.935	-97.265	-12.822	110.048
December	-64.792	75.525	-301.053	-97.946	-26.190	102.672

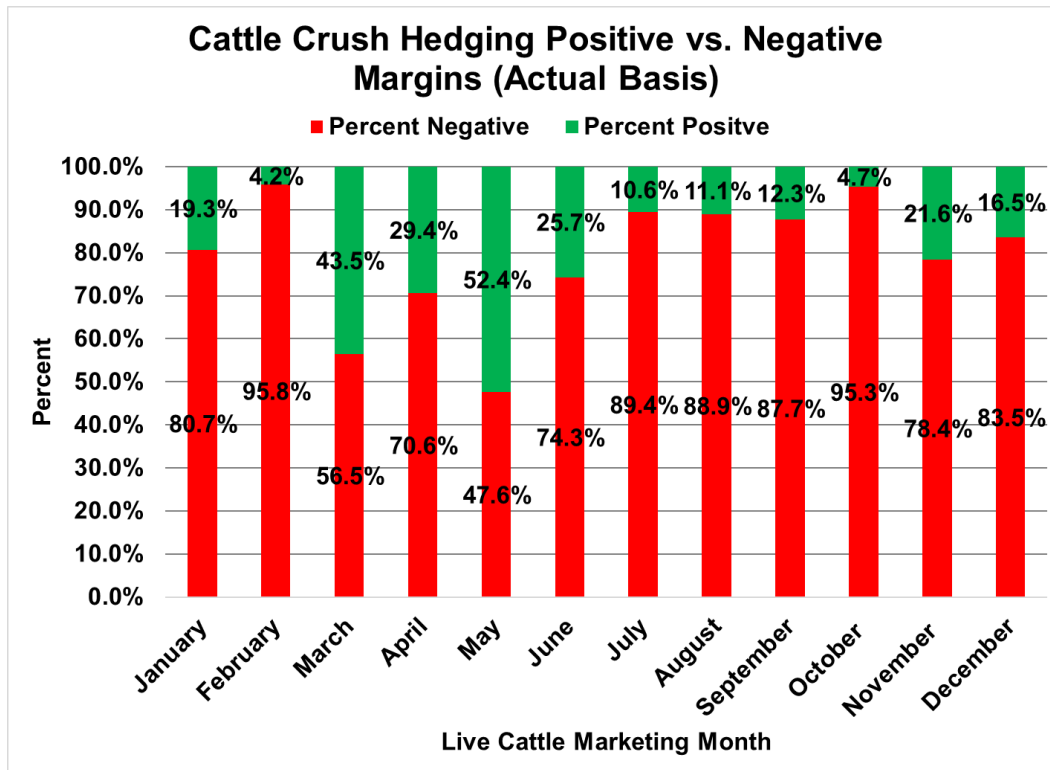


Figure 8: Percent positive and negative margins calculated with actual basis from cattle crush hedging, grouped by anticipated marketing month.

the poorest crush hedging margins occurred in February, where only 52 of 1232 margins were positive, and the lowest average was offered. One of the more interesting aspects of crush margin results is the mostly inverse relationship between margin quality and standard deviation. As margins improved in the spring months of March and April, the standard deviation rose to the highest levels seen over the course of a year. On the other hand, when the poorest crush margins are observed, in February, the standard deviation reaches its lowest point for the year.

Ultimately, as cattle crush hedging margins improved so too did the variability associated with offered expected margins.

Evaluating cattle crush margins on an intra-year basis provides insight as to when may be the most lucrative time to engage in cattle crush hedging. Still using the same set of cattle crush

hedging margins calculated with actual basis, Figure 9 shows the minimum, average, and maximum margins offered to each of the 573 base observations. By examining cattle crush

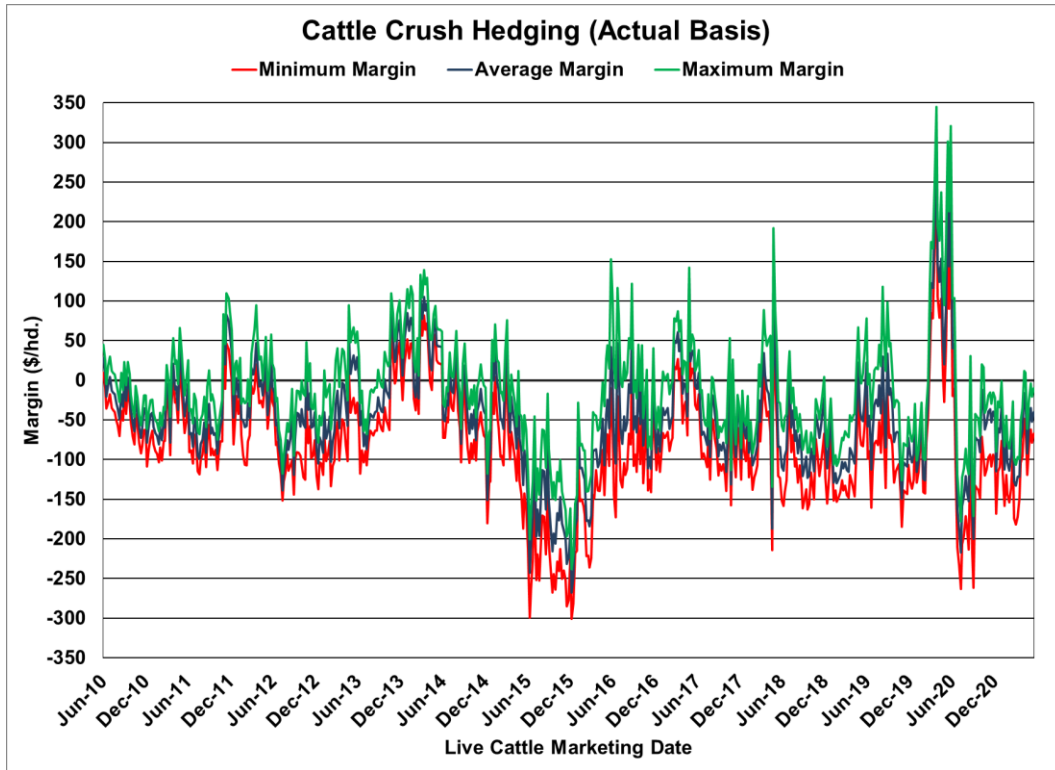


Figure 9: Average, Minimum, and Maximum Cattle Crush Hedging Margin offered throughout the study period.

hedging margins across the study period, cattle feeders can get an idea of the margin opportunities offered by the cattle crush hedging strategy. This information is valuable to cattle feeders in their decision-making process as it provides a gauge of margins offered through cattle crush hedging. In doing so, cattle feeders can answer the question of whether they want to secure the margin that is being offered by the commodity futures market today, or wait.

When the cattle crush hedging strategy offers positive margins, in Figure 9, most opportunities exist in the \$0 - \$50 per head range. To a lesser extent, there are still opportunities to secure a margin of \$50 - \$100 per head using cattle crush hedging. The minimum series

spends the least amount time in this range. Both the average and maximum series offer significantly more opportunities between \$0 and \$100 per head. When evaluating cattle crush hedging margins, if the futures markets offer a margin within the range previously mentioned, a cattle feeder may strongly consider securing it. Even though Figure 9, shows cattle crush hedging margins can move above \$100 per head, it is typically the maximum series doing so. While picking the maximum cattle crush hedging margin is possible, it is difficult as the margin only occurs once. If a maximum margin is secured it is much more a function of chance than anything else. The average series encompasses all crush margins offered to each turn of cattle, thus it is more representative of what realistically could have been secured.

On the other side of the horizontal axis in Figure 9, negative margins offered to each base observation are shown. Levels offered during periods of lower trending margins are typically between \$0 and -\$100 per head. This information is valuable to cattle feeders as negative margins would only typically be secured if an individual had a negative outlook on the market. In other words, they are expecting margins to continue to move lower. If this is the case, a cattle feeder should look for a cattle crush hedging margin that is close to the \$0 to -\$100 per head range to limit losses. In times of decreasing margins, waiting to secure margin is likely to result in opportunities that may be less ideal in live cattle hedging or cash markets.

To round out the discussion focusing on cattle crush hedging, Figure 10 illustrates the entire vector of cattle crush hedging margins calculated with actual basis. The feeder cattle, corn, and live cattle commodity futures markets offered a positive cattle crush hedging margin in every year studied. Result data are rangebound and rarely make large swings in either direction. Ultimately, multiproduct hedging is most effective at reducing risk. This analysis has been critical of the fact that cattle crush hedging shifts the average margin lower. Though it is

important to note, just because a margin is negative does not necessarily make it unfavorable. There are times throughout the study period where the goal of the cattle feeder would have been to limit losses when positive margins were unavailable. In 2015, when cattle feeding margins bottomed out, the worst crush hedging opportunity was around -\$300 per head. This is markedly greater than lows established by other margin strategies. Multiproduct hedging tended to offer margins that were closest to a break even no matter the direction margins were trending. To sum up, though it is infrequent that the market offers lucrative margins prior to the commencement of the feeding period, cattle crush hedging still serves as a valuable tool to cattle feeders.

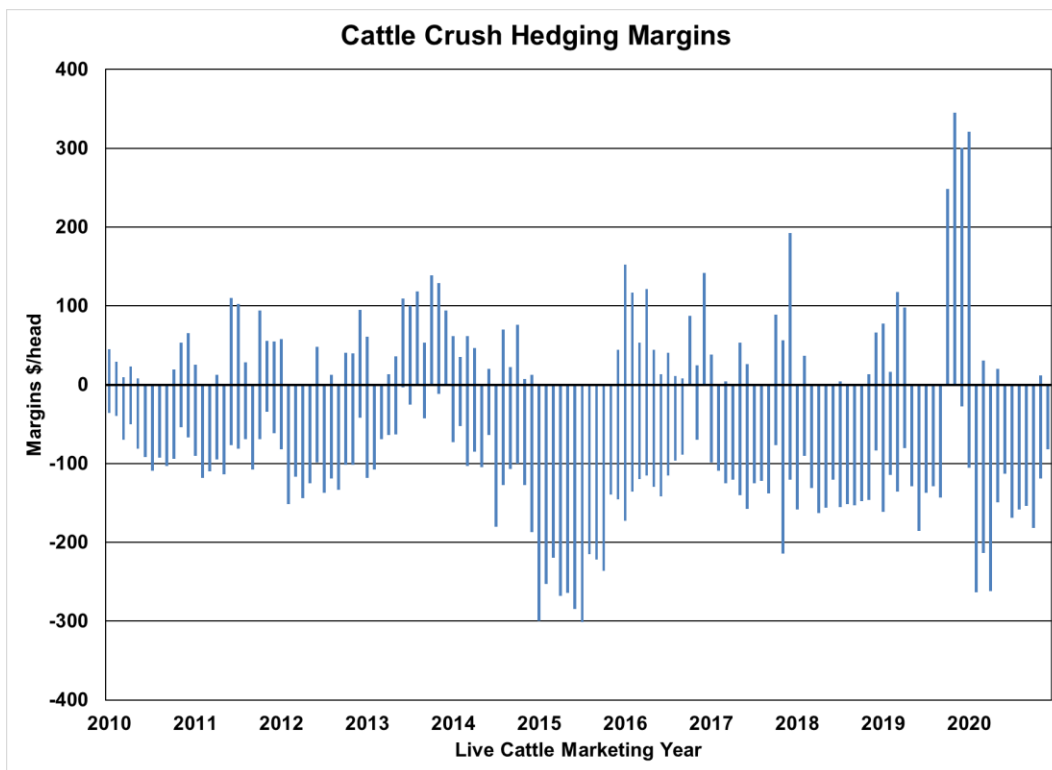


Figure 10: All margin results using the actual basis from the cattle crush hedging strategy.

5.2.2 Live Cattle Hedging

Evaluating result data from live cattle hedging, cattle feeders would be most motivated to engage in live cattle hedging in the first six months of the year. March and April are the strongest

months. Not only was the greatest average margin exhibited in these two months, but three quarters of live cattle hedging opportunities resulted in positive margins. Remaining months in the first half of the year offer ample positive margins opportunities, as shown in Figure 11. In the second half of the year, positive margin opportunities diminished, as roughly two-thirds of margins offered were negative. For the most part, in Table 6, average margins progressively worsened reaching lows in December. November, however, is an exception in the second half of the year. Average margins improve for this month as more than half of margin opportunities were positive. Strong spring and late fall margins, separated by a weaker late summer and fall further highlight the seasonality of margins discussed in the last section.

Table 6: Live Cattle Hedging Margins Summary Statistics by Projected Marketing Month

Live Cattle Hedging Margins (Actual Basis/Per Head)						
Marketing Month	Mean	Standard Deviation	Minimum	25th Percentile	75th Percentile	Maximum
January	-0.529	110.014	-511.105	-54.039	66.447	300.012
February	5.602	105.835	-362.063	-56.012	70.462	300.487
March	59.683	99.768	-250.427	-0.197	118.098	407.231
April	68.753	113.417	-430.785	4.980	142.461	383.697
May	44.722	139.093	-429.053	-45.846	145.410	468.882
June	-21.271	143.387	-508.612	-124.800	72.287	415.691
July	-46.893	120.368	-388.174	-131.150	16.362	384.334
August	-44.090	121.217	-301.620	-123.163	15.004	359.587
September	-51.957	101.387	-361.752	-114.206	0.809	260.044
October	-43.998	108.636	-501.882	-102.704	15.293	320.058
November	-15.921	121.111	-456.448	-87.562	65.796	315.638
December	-55.290	130.350	-629.267	-115.961	29.925	231.792

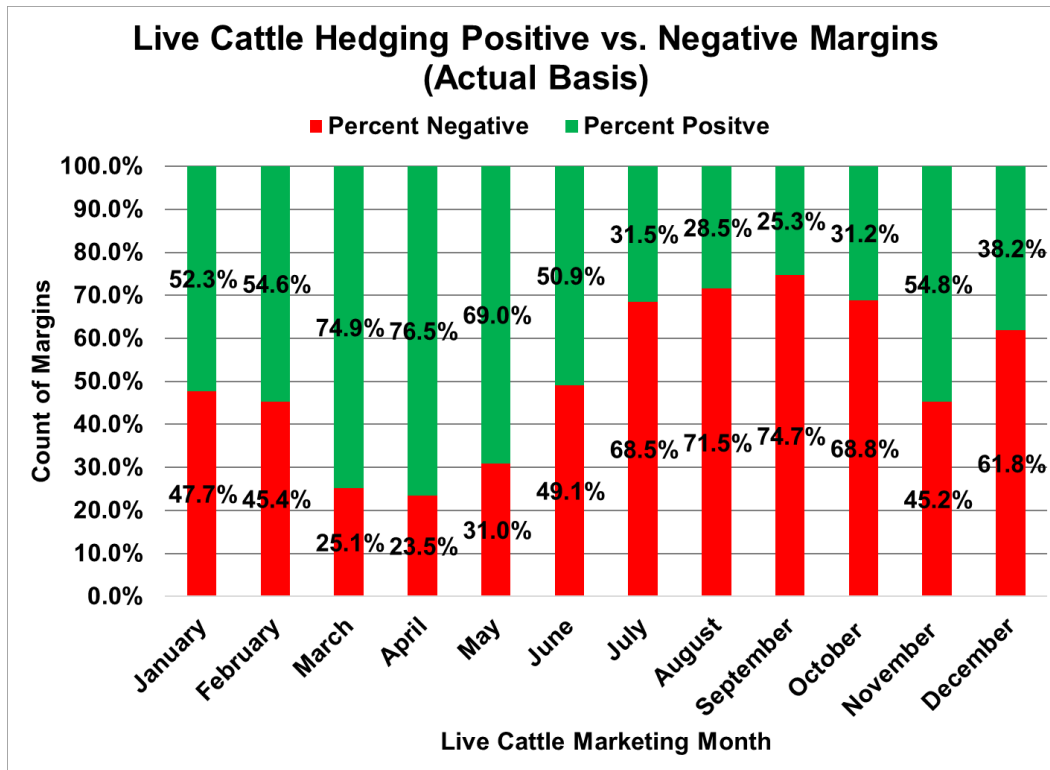


Figure 11: Percent positive and negative margins calculated with actual basis generated by live cattle hedging.

Again, this analysis shifts to evaluating live cattle hedging margins offered over the course of the study period. Figure 12 shows the average, minimum, and maximum live cattle hedging margins determined with actual basis offered to each base observation. Like benefits derived from examining Figure 9, Figure 12 allows a cattle feeder to see the various degrees of margins offered by the live cattle hedging strategy. This illustration will better inform individuals of the kind of margins that may be available after purchasing feeder cattle, and over the course of the on-feed period.

Positive margin opportunities offered through live cattle hedging typically exist in a range between \$0 and \$150 per head. While there are some live cattle hedging margin opportunities greater than \$150 per head, it is rare for them to move above \$200 per head.

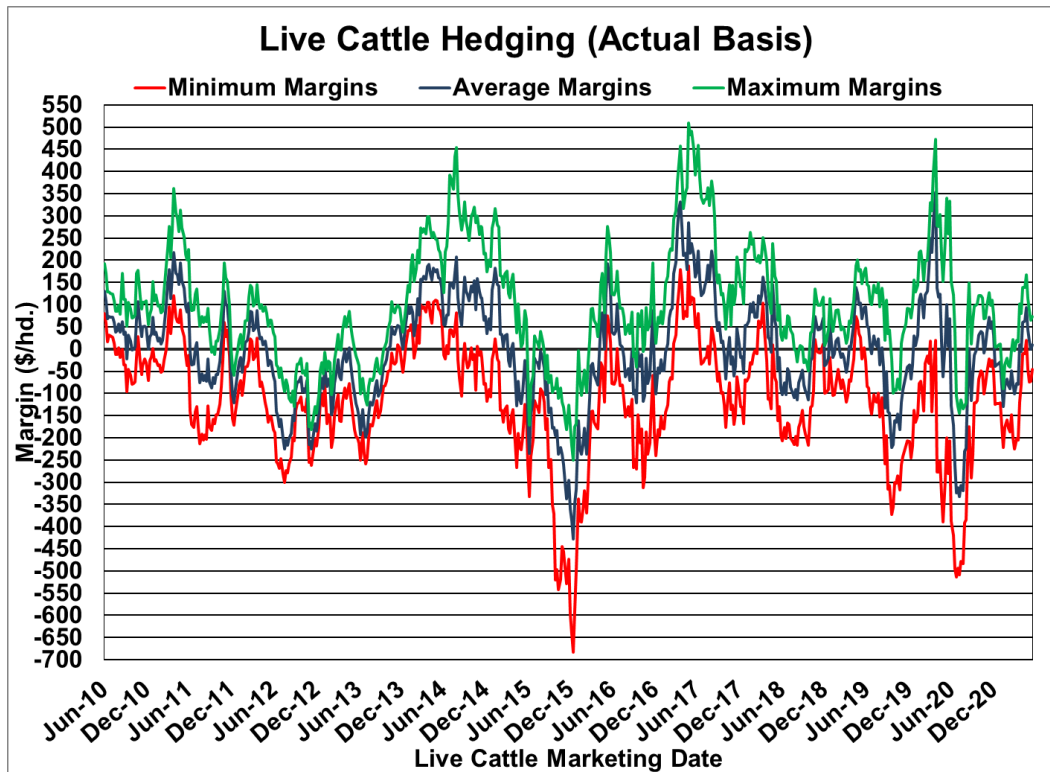


Figure 12: Average, Minimum, and Maximum Live Cattle Hedging margins offered throughout the study period.

Maximum margins offered to each base observations only move above the \$200 mark on six occasions. The average margin series only moves above \$200 per head twice. These results suggest that if the futures market offers a cattle feeder between \$100 and \$200 per head, this hedge should be executed. Whereas, if the live cattle hedging margin is between \$0 and \$100 per head a producer may be more cautious, or less aggressive in their hedging practices. The reason for this is that live cattle hedging offers ample margin opportunities above this range. But, some level of live cattle hedging may be beneficial, as a positive margin would be preferred to one that is negative. The decision made here will strongly depend on the direction in which margins are thought to be trending.

When live cattle hedging offered negative margins Figure 12 depicts margins worse than -\$150 per head are unusual. Even though minimum margins regularly fall past this limit, cattle

feeders would try to avoid these extreme negative margins. Average margins only decreased past -\$150 on six instances across the study period. Across most observations, live cattle hedging offered a margin that was much closer to a breakeven or even positive at some point during the cattle feeding period. Granted, there were periods when this improved margin may have been the maximum margin offered. Previous discussions have covered the difficulties associated with securing the maximum margin.

Margin results from live cattle hedging were quite favorable over the study period. Figure 13 shows the entire vector of live cattle hedging margins calculated with actual basis. Having these levels of profit opportunities is significant in a margin-oriented business that simply tries to breakeven in many cases. The same years that were problematic for cattle crush margins are the same years that are problematic here. Even though negative margins existed over the course of the study period, the benefit of live cattle hedging is that producers are not necessarily forced to accept negative margins. Hedging allows producers to search for optimal margins. The issue though is that the market may never offer a positive margin on a turn of cattle. Live cattle hedging reduces risk observed in cash margins and is less restrictive than the multiproduct hedging strategy.

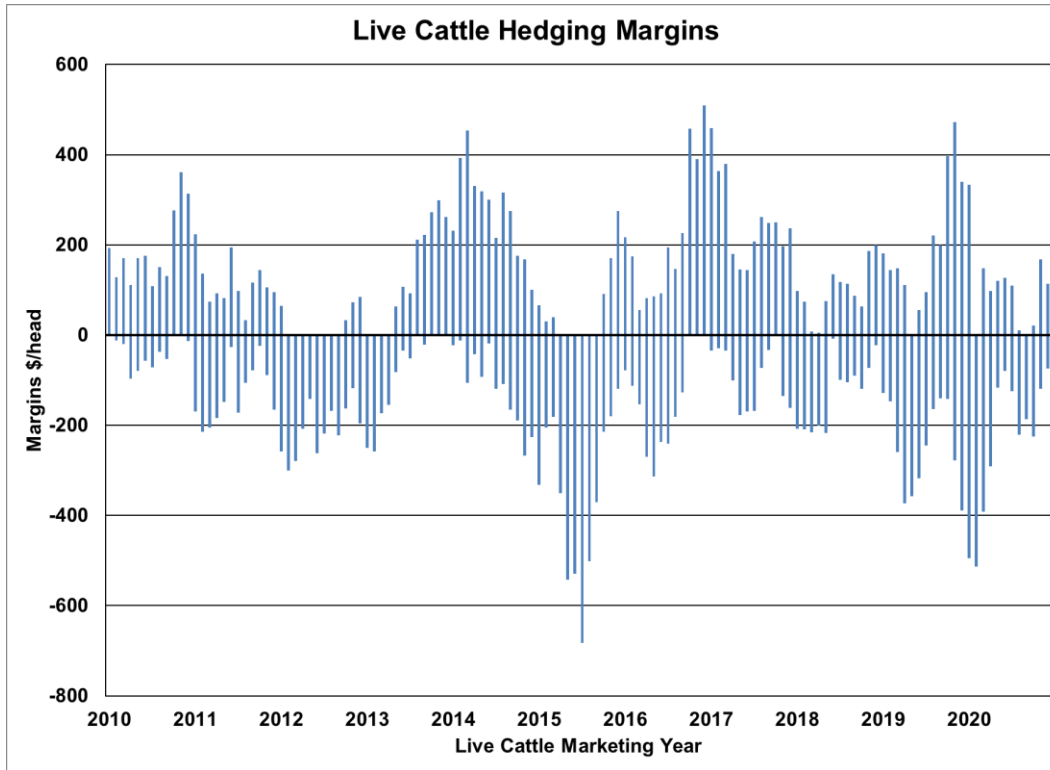


Figure 13: All margin results using futures prices corrected by actual basis from the live cattle hedging strategy.

5.2.3 Cash Margins

Cash margin results suggest that cattle marketed at either the beginning or the end of a year are typically offered the best outcomes. Cattle shipped in January through March garnered the greatest average margin, as shown in Table 7, and one half or more of resulting margins were positive in Figure 14. Towards the opposite end of a year, while the monthly average may have not been as high, there were still many profitable cash opportunities in October through December. Table 7 illustrates that through the late spring and early fall average margins steadily declined into September, where on average cattle garnered -\$48 per head. Even worse during this time frame was how quickly positive margin opportunities disappeared.

Table 7: Cash Margins Summary Statistics by Projected Marketing Month

Cash Margins (Per Head)						
Marketing Month	Mean	Standard Deviation	Minimum	25th Percentile	75th Percentile	Maximum
January	34.913	131.302	-300.236	-32.919	119.520	287.242
February	29.838	132.890	-215.897	-66.812	115.109	315.725
March	43.219	159.405	-202.549	-69.249	151.910	432.843
April	22.096	173.240	-317.649	-85.235	174.698	443.006
May	6.532	157.057	-236.719	-89.591	96.629	485.854
June	-26.791	168.950	-308.184	-146.743	103.325	371.404
July	-27.370	166.487	-285.152	-124.799	91.224	398.383
August	-9.230	144.086	-244.486	-88.548	67.611	392.909
September	-48.964	149.404	-347.256	-145.785	9.416	358.627
October	-9.140	182.065	-487.917	-123.684	61.497	414.894
November	20.296	186.578	-465.656	-17.665	118.471	379.171
December	0.674	179.358	-573.378	-3.454	98.751	219.767

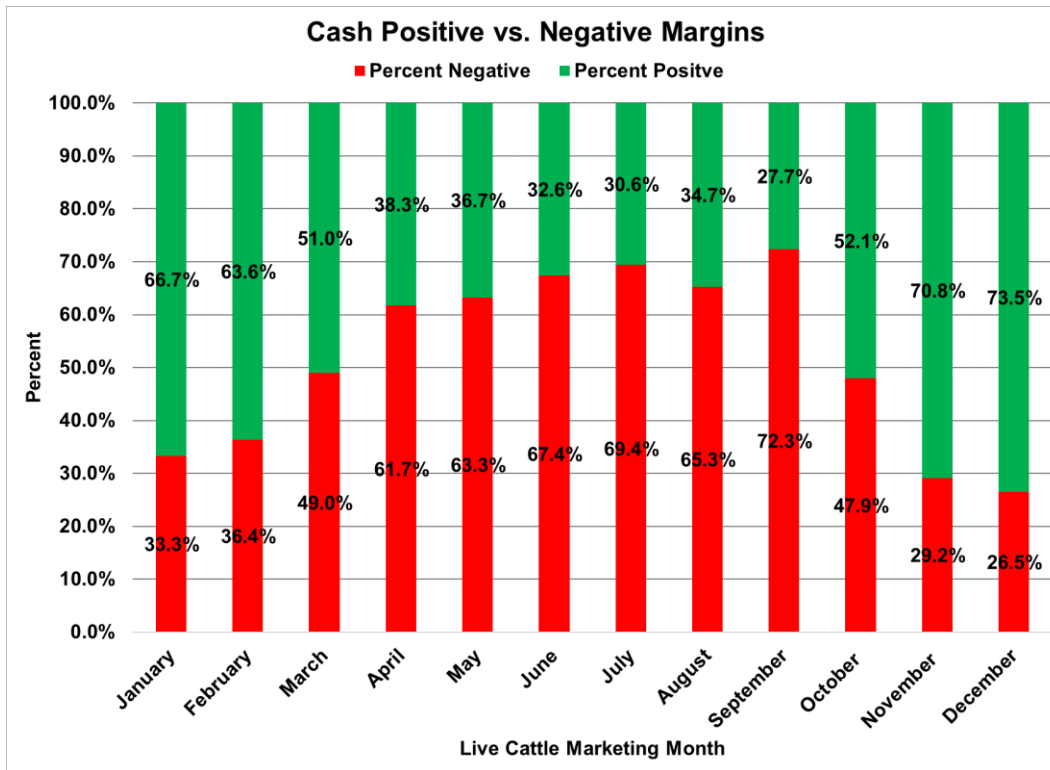


Figure 14: Percent positive and negative cash margins over the study period.

In April through September, Figure 14 shows more than 60 percent of margins offered by physical markets were negative. For the cattle feeder, it is useful to know when cash margins perform, as there may not be as much urgency to fully hedge every head of cattle in their possession. However, the hedging pressure is much more significant into spring and early fall when cash margins tend to struggle.

Margin results offered in the cash market fluctuated between positive and negative regularly. Positive cash margins were offered each year of the study. However, this is certainly not to say every base observation received a positive opportunity in the cash market. In fact, there are extended periods of time when positive cash margins are consistently unavailable. As mentioned previously, results from the cash margins strategy can turn very quickly. In 2014, a cattle feeder at one point was making around \$400 per head. The very next year, they were

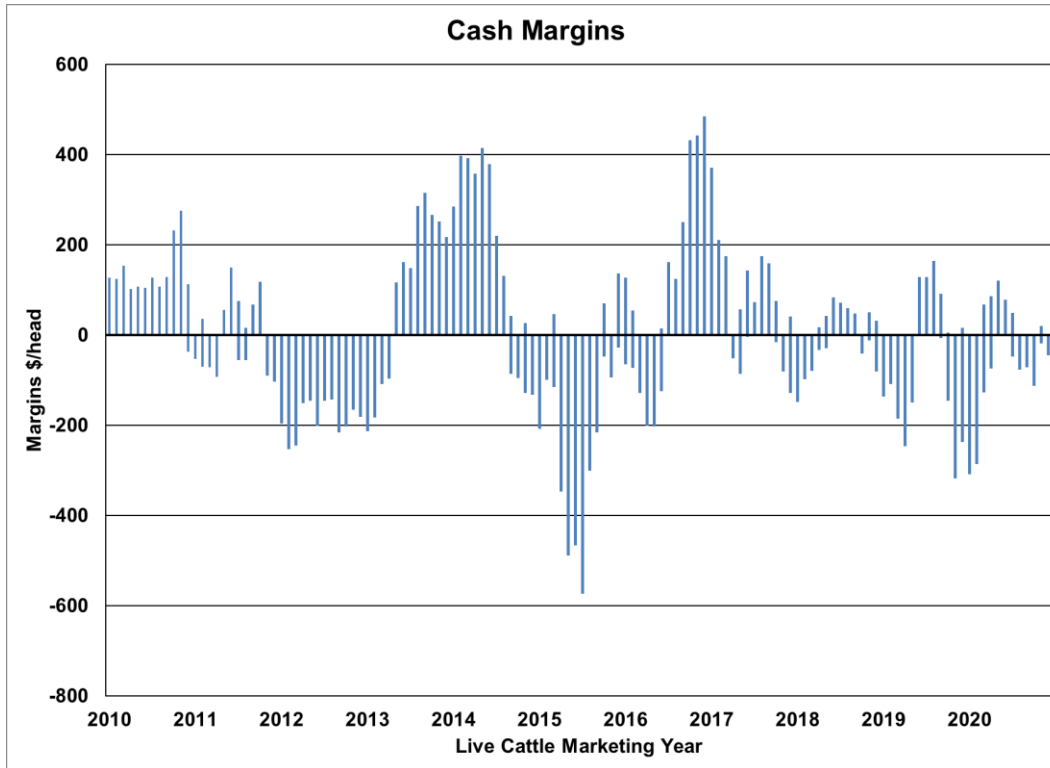


Figure 15: All cash margin results.

losing over \$570 on every animal placed on feed. Cattle feeding garnered significant profitably in one year and it was all lost in the next. Variable profits are an issue individuals in this sector have become accustomed to. It is a significant reason individuals implement risk management, as there is more than one opportunity to secure a margin, and volatility is lowered significantly.

5.3 Fundamental Market Factors

Live cattle markets, whether physical or commodity futures, as well as other markets are driven at least in part, by fundamentals in the marketplace. Fundamental factors are primarily those elements that impact supply and demand. A cattle feeder would be concerned with the supply and demand of both inputs as well as their output. If feeder cattle and corn are in short supply this would be indicative of rising input costs. The opposite, larger supplies of feeder cattle and corn, would likely lower the costs of producing live cattle. Increasing and decreasing costs

certainly impact the quality of both expected and actual margins. Supply and demand of live cattle would also be an important variable followed by cattle feeders. If supplies of live cattle are elevated, live cattle futures and cash prices may be reduced as there are ample numbers of finished cattle to process. Conversely, if supplies are tight, and demand is high live cattle prices shift higher. Like costs, changing revenues would be a significant factor in any type of margin. For these reasons, it is important to begin to understand the affects various fundamental factors have on cattle feeding margins. Fed cattle prices, United States beef cow inventories, and cattle slaughter are fundamental factors examined as a part of this research. For this portion of the analysis only margins calculated with actual basis are considered.

Margins results, as well as the annual average margin from each strategy are plotted against year-to-year changes in live cattle cash prices. The purpose of Figures 16 through 18 is to illustrate how margins from each strategy perform under changing fed cattle price environments. Starting with margin extreme points, in Figure 16, it is observed that in decreasing price environments the maximum and minimum cattle crush margins are attained. Live cattle hedging margins, in Figure 17, are similar in that the lowest margins are established during decreasing prices. However, they differ in that the maximum live cattle hedging margin is set when prices were mostly steady. Cash margins, in Figure 18, set their extreme points under the same price conditions as margins from live cattle hedging. It was initially thought, maximum margins would have occurred when changes in year over year prices were more positive.

The way in which margins vary across different price environments is quite similar for each marketing strategy. In periods of reduced prices, margins are much more spread out, indicating heightened levels of variation. Margins garnered during periods of increasing prices tend to be clustered much closer together, suggesting that levels of risk are decreasing.

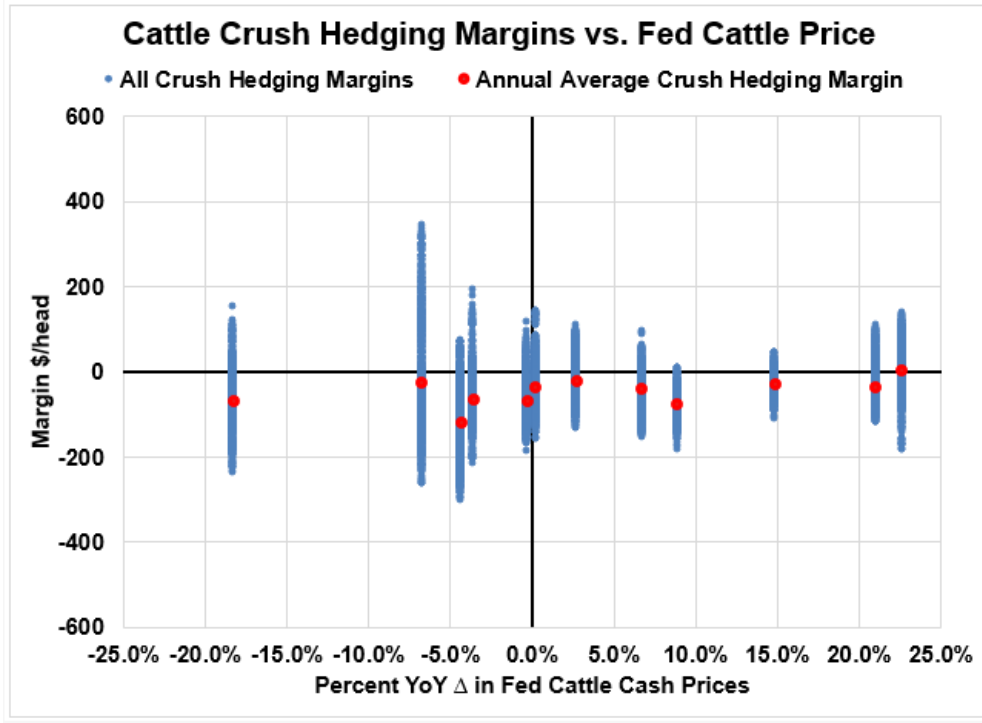


Figure 16: Cattle crush hedging margins and the year-to-year changes in live cattle cash prices.

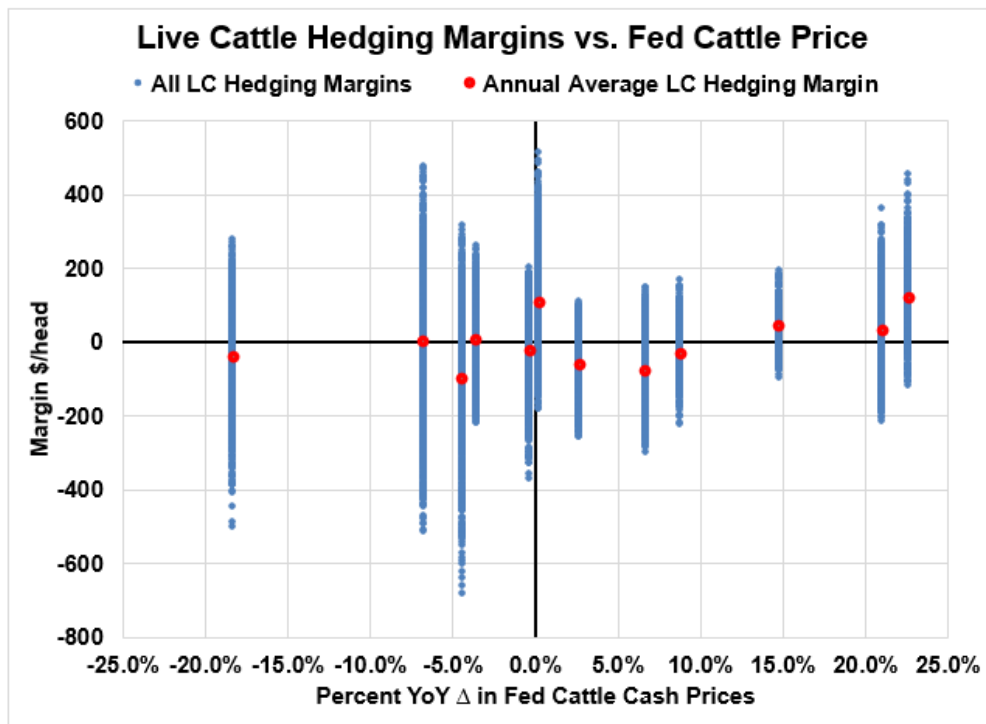


Figure 17: Live cattle hedging margins and year-to-year changes in live cattle cash prices.

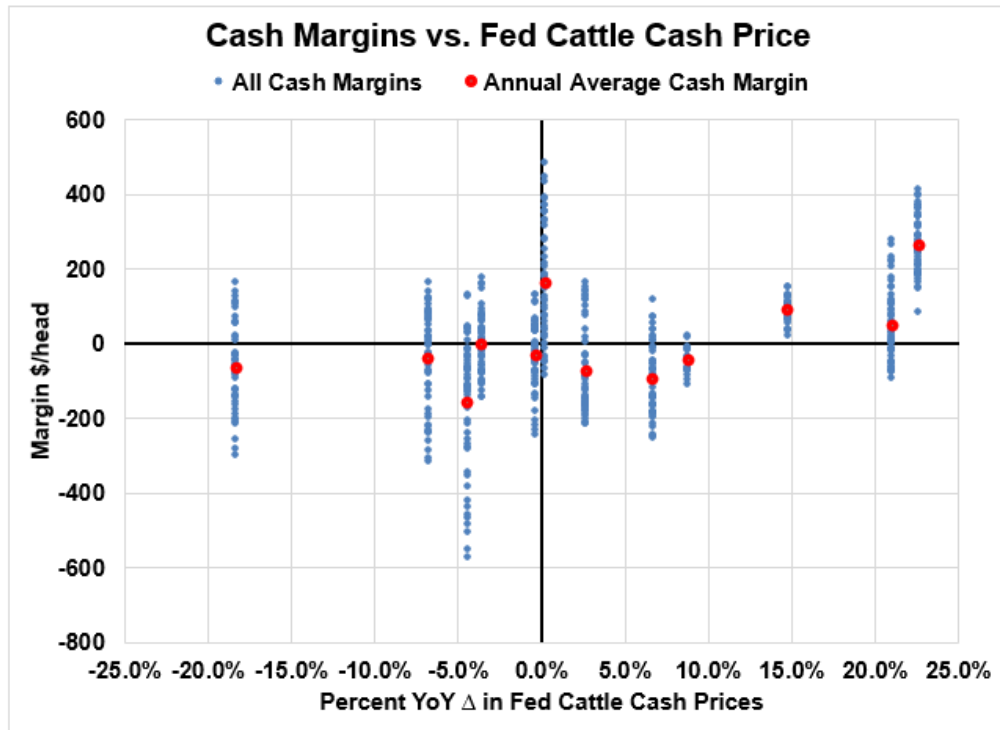


Figure 18: Cash margins and year-to-year changes in live cattle cash prices.

Annual average cattle crush margins exhibited no distinct pattern in Figure 16. Annual margin averages for live cattle hedging, in Figure 17, as well as cash margins in Figure 18, were arranged in a manner that was much more consistent with research expectations. The expectations were that increasing price environments would shift average margins higher.

In Figures 19 through 21 margins from each strategy is plotted against changes in the previous years' beef cow inventory. As cattle are marketed at about one year of age, it would not be logical to compare beef cow inventories and margins of the same year as the prior year's calves are the group of cattle being marketed. The reason for plotting margins against last year's cow inventory is to examine how both feeder cattle and subsequent live cattle availability impacted margins. Margin variation under changing cattle inventories seems to depend on the strategy being evaluated. Cattle crush hedging, in Figure 19, results in less variation at reduced inventories and variation rises with increases in inventory. For the most part, live cattle hedging

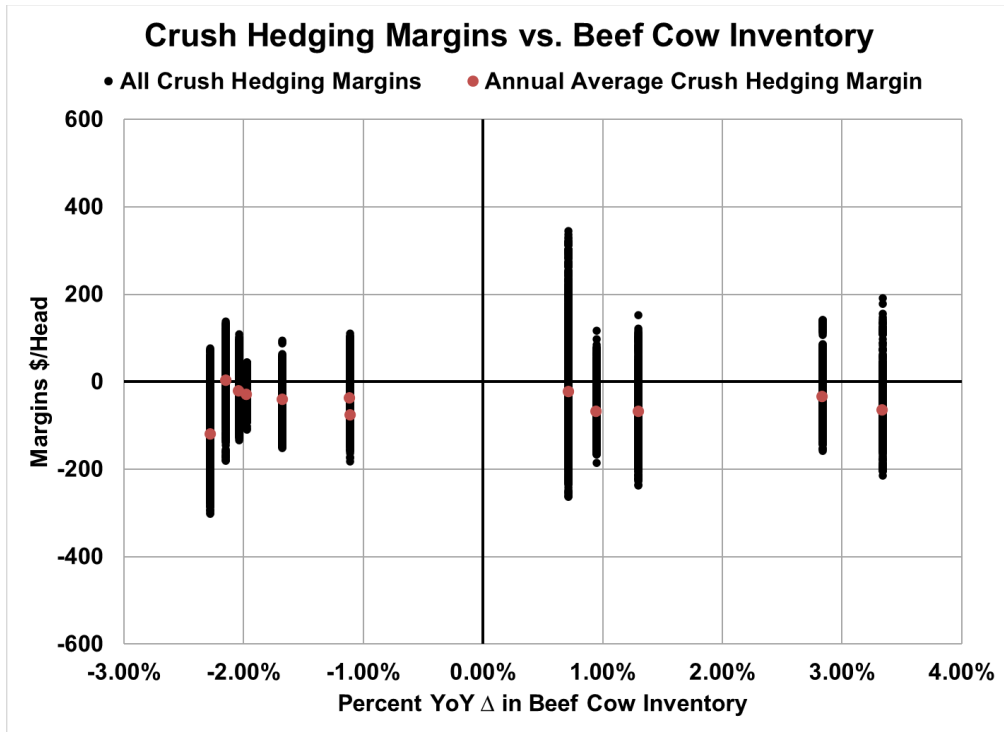


Figure 19: Crush hedging margins and prior year changes in the United States beef cow inventory.

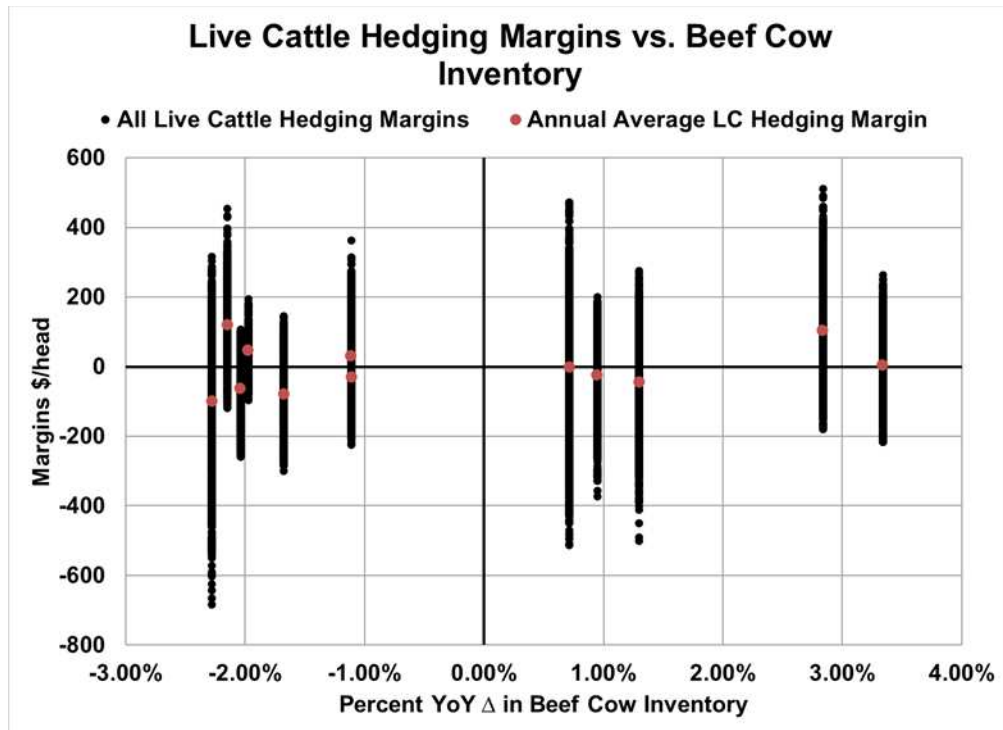


Figure 20: Live cattle hedging and prior year changes in the United States beef cow inventory.

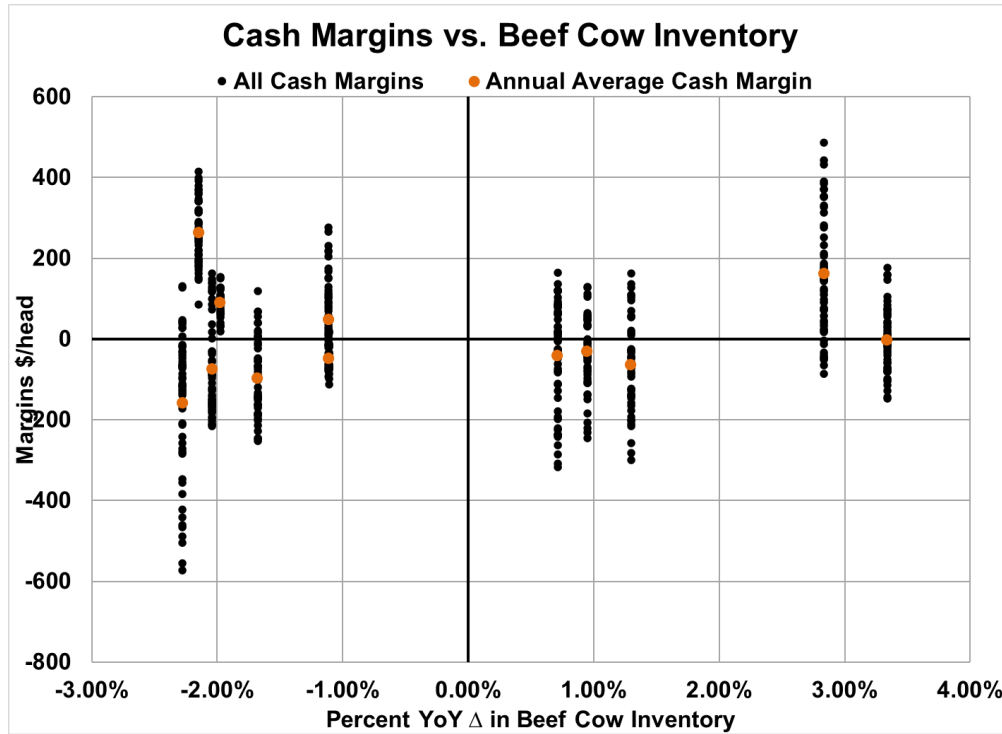


Figure 21: Cash margins and prior year changes in the United States beef cow inventory.

in Figure 20, has slightly smaller variation when changes in inventory are negative. For cash margins in Figure 21, it is not clear which end of changes in beef cow inventory results in more margin variation.

Each strategy sets maximum margins during periods of elevated cow numbers and minimum margins when the cow herd is contracting. Looking at annual average margins across each strategy, there are different trends established. Crush hedging average margins show that as the cow herd increases the average shifts lower. For live cattle hedging and cash margins, while the trend is subtle, average annual margins increase as the percent change in beef cow inventory rises. Both trends are logical from a supply and demand perspective. More beef cows would result in a larger supply of feeder cattle. Elevated feeder cattle supply benefits cattle feeding margins, by reducing the price of that input. Thus, validating the trend of annual average margins observed in live cattle hedging and cash margins, in Figures 20 and 21. Looking to the other end

of the production chain, increasing inventories of beef cows, producing more feeder cattle, would also result in elevated supplies of live cattle that must be marketed. This would be more of a hinderance to cattle feeding margins as output prices shift lower. Thus, the trend of a lower annual average margins with increasing beef cow inventories exhibited by crush hedging, in Figure 19, is also valid. Opposing effects of beef cow inventories on cattle feeding margins are further highlighted by looking at margin levels across each strategy. There were positive margins offered while the cow herd was in a contraction phase, and negative margins during expansion. As a result, an all-encompassing conclusion on how changes in beef cow inventory impacts cattle feeding margins is difficult to make.

The final fundamental factor measured against margin results is annual live cattle slaughter volume. The purpose of Figures 22 through 24 is to evaluate how margins from each strategy perform under various levels of live cattle slaughter. Across different strategies similarities and differences are discovered. For all margin strategies the lowest margins are set when annual slaughter totaled 22.6 million head. This is in line with expectations in that the lowest margins occurred during a year when the lightest volume of fed cattle slaughter was observed. To the other extreme, maximum margins occurred at increased slaughter levels, 25.1 million head for crush hedging margins, in Figure 22, and 25.4 million head for both cash and live cattle hedging margins, in Figures 23 and 24.

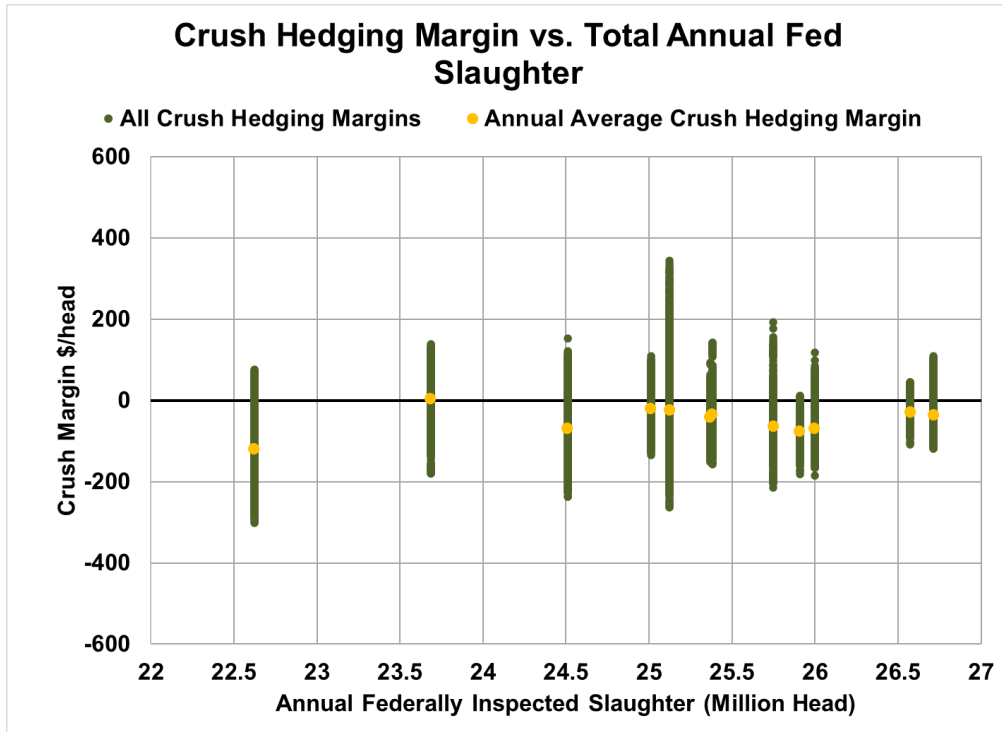


Figure 22: Crush hedging margins and year-to-year annual volumes of fed cattle slaughter.

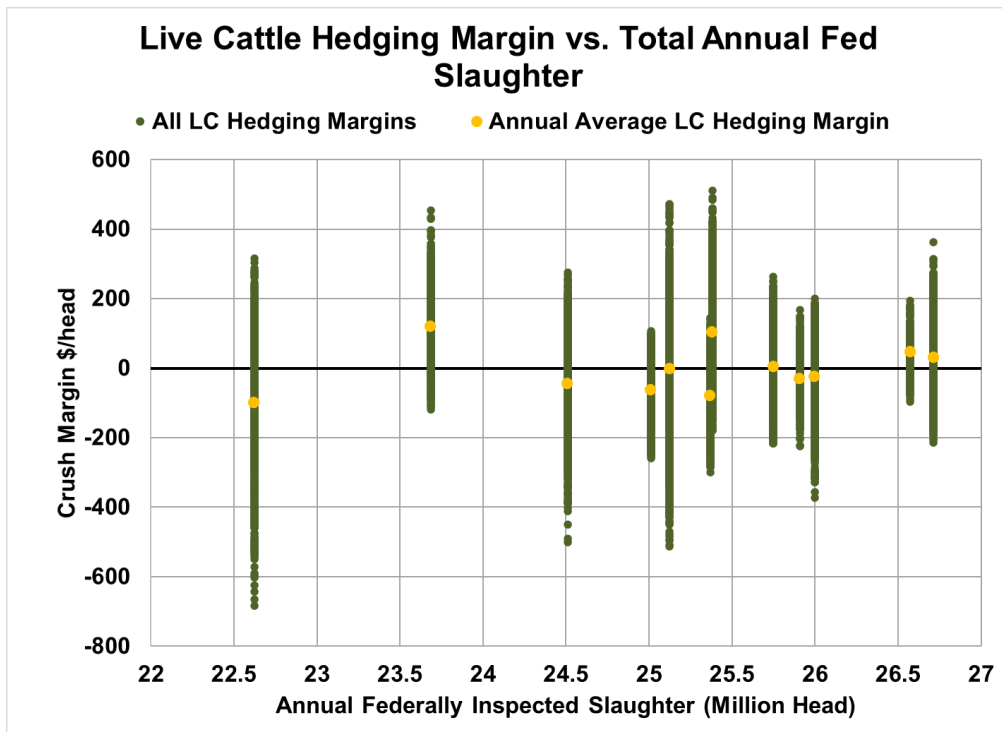


Figure 23: Live cattle hedging margins and year-to-year annual volumes of fed cattle slaughter.

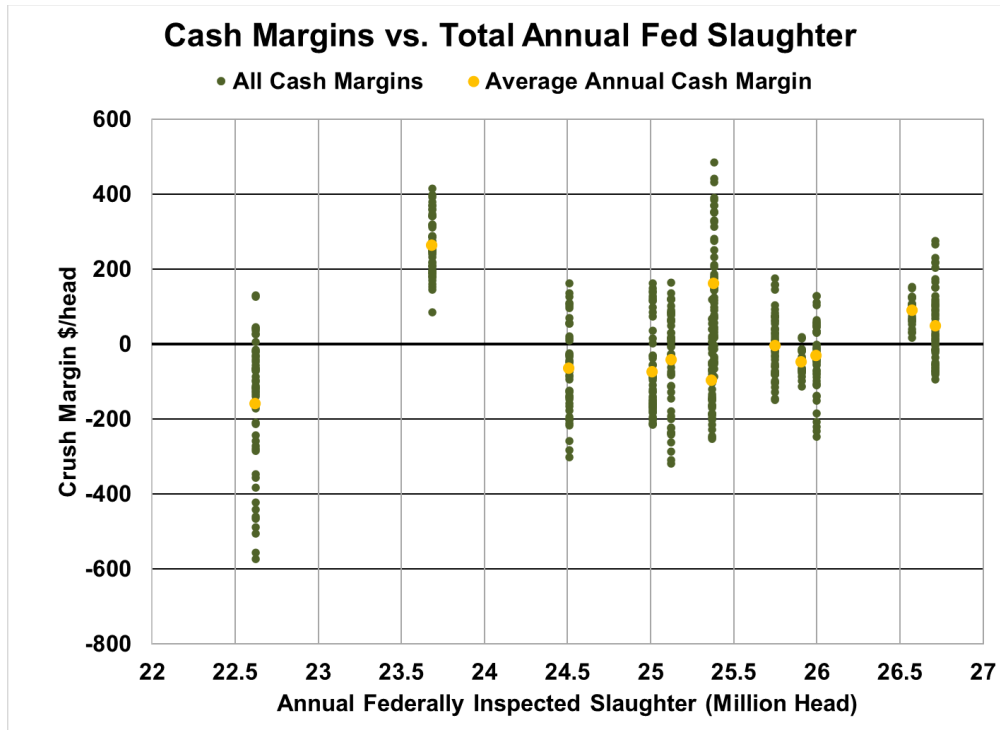


Figure 24: Cash margins and year-to-year annual volumes of fed cattle slaughter.

Evaluating the impacts of fed cattle slaughter on margin variation, all three margin strategies appeared to exhibit similar patterns. Below the annual slaughter mark of 25.5 million head, margins are much more dispersed from high to low. Above this point, expected and actual margins displayed less volatility. Once live cattle slaughter reaches elevated levels, margin risk is reduced. The trend in annual average margins is the same across each strategy. As slaughter increases, the mean shifted higher.

These results signal that awareness of various fundamental factors can benefit cattle feeders in their risk management decision making. Year over year changes in live cattle prices can be informative of the level of risk a cattle feeder may face. If increasing prices are expected then, less hedging may be executed, and if so, live cattle hedging may be the preferred strategy as higher margins are attainable. Oppositely, if prices were to decrease more aggressive hedging strategies may be necessary, and multiproduct hedging may be more practical for its ability in

reducing standard deviation. Previous year's beef cow inventories are useful in that it is known even before crush margins can be considered. If beef cow levels are known to be contracting, then feeder cattle will be less readily available. In this case, a cattle feeder will want to closely monitor margins offered by the commodity futures market. Hedging may be necessary to protect against rising input costs, output prices will likely be increasing as the live cattle supply becomes tighter. Lastly, knowing the expected fed cattle slaughter environment can aid in making optimal decisions from a risk management standpoint. As slaughter increased, margin opportunities shifted higher. If a particular year is expected to have an annual fed slaughter volume of more than 25.5 million head, a cattle feeder may not want to engage in as many hedges, as margin variation over this level is minimal. If slaughter is thought to be lower, more hedges may be necessary as variation increases. If a cattle feeder's risk aversion is high, then multiproduct hedging may be implemented. If the individual is willing to accept more risk, then single commodity hedging may be the strategy of choice.

5.4 Cost of Gain Model

Use of the COG model was beneficial to this research in that it offers a more accurate portrayal of what happened in practice. In reality, feed and other costs can change both inner- and intra-year. For example, corn needs can vary based on the time of year and the type of cattle being fed. Other costs can change as result of factors such as weather and the current labor market. The use of a model allows feed and other costs to vary across time. Results from the Ordinary Least Squares (OLS) regression used to estimate the COG model are shown in Table 8.

In terms of how well the model fits the data, 80 percent of changes in the dependent variable are accounted for by the model. Where the F-Statistic is significantly larger than the critical value, the null of each independent variable being equal to zero can be rejected.

Table 8: COG Model Results

Variable:	Coefficient	Standard Error	p-value
Intercept	2.608	4.682	0.578
Natural Log Lagged Corn Price	55.491	2.448	<0.0001 ***
Trend Variable	0.061	0.015	<0.001 ***
February	2.258	2.821	0.425
March	1.789	2.821	0.527
April	0.931	2.767	0.737
May	-0.779	2.767	0.779
June	-2.649	2.822	0.350
July	-3.117	2.822	0.271
August	-2.989	2.822	0.291
September	-2.983	2.822	0.292
October	-1.610	2.821	0.569
November	0.152	2.823	0.957
December	-0.660	2.823	0.815

F-Statistic: 43.88

R² : 0.794

Residual Standard Error: 6.91

<0.001(***),0.01(**),0.05(*)

Evaluating independent variables in the model, it is observed that only two variables are highly significant and remaining variables are not. These two variables are highly significant, at less than a 1 percent level of significance. The natural log of the lagged corn price and the trend are important determining factors of costs of gain. The coefficient on the natural log of the lagged corn price is interpreted in such a way that a one percent increase in corn price would result in total cost of gain rising by more than 5 percent, all else equal. The trend variable suggests costs of gain are trending upward throughout the study period. In each month, \$0.06 is added to the cost of gain through this variable, again holding everything else equal. The binary month variables, though not statistically significant in this model, show how costs of gain change on a seasonal basis. They indicate that through the late spring into early fall costs of gain are much lower. Whereas, during the winter months of December through March costs are more elevated.

At least part of the increase in costs of gain can be attributed to weather conditions over the winter. In the primary cattle feeding region of the U.S. winters tend to be colder, and depending on the year can be wet. During cold and wet conditions, cattle exert more energy towards maintenance rather than weight gain. This results in weight gain during poorer weather windows being more expensive. Figure 25 illustrates the model plotted against the observed data points.

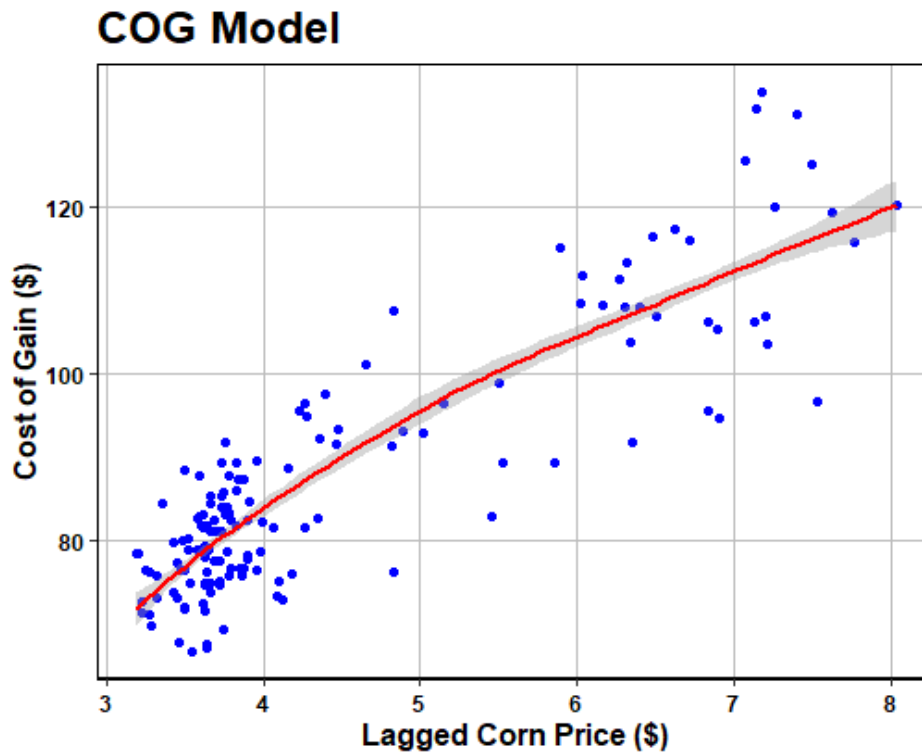


Figure 25: COG model including the natural log of corn price, trend, and seasonality.

CHAPTER 6: SUMMARY AND CONCLUSION

The United States cattle feeding sector has long been known to endure significant margin volatility. Price risk observed in both primary input markets as well as the output market is a contributing factor to margin volatility, as discovered by Noussinov and Leuthold (1999). Risk management strategies are applied to reduce price risk. To better inform risk management decision making, a cattle feeder can evaluate margins offered to them in both the commodity futures and cash markets. This research evaluates expected margins offered through single commodity and multiproduct hedging, as well as actual margins in the cash market. The main objective of this study was to identify the mean and variance associated with expected margins from both hedging strategies and actual margins. The purpose in doing so, was to provide insight into the opportunities and risk in both the cash and commodity futures markets. Data for this research was compiled from a variety of sources. Expected and actual margin equations were then constructed. Two methods of basis were used to adjust futures prices, so that impacts on margins could be studied. A model was developed to forecast costs of gain well in advance of placing cattle on feed. The remainder of this chapter will detail conclusions made for each margin strategy and how each performed over the course of the study period. To close, the implications this research has for cattle feeders are discussed along with future directions for this research.

Since previous research, the mean of cash margins has shifted lower, while standard deviation has increased by over \$100 per head (Schroeder & Hayenga, 1988). However, cash margins still offered the highest mean, relative to either live cattle hedging or cattle crush

hedging. The issue here, is the level of risk that is associated with actual margins in the cash market. Cash margins tended to move the furthest in either direction, which resulted in the greatest margins when cattle feeding returns were at maximum points. When margins shifted lower, there was no limit to how far and fast they could fall. This level of risk is substantial for cattle feeders.

It was rare for the commodity futures market to offer profitable margin prior to the start of the cattle feeding period. This research differs from what has been done previously, in that expected margins from cattle crush hedging offered the lowest mean of any margin strategy. However, this research is similar in the fact that crush margins were unmatched in terms of the level of risk reduction offered (Spahr & Sawaya, 1981). Cattle crush hedging expected margins offered the lowest standard deviation compared to either cash or single commodity hedging margins. While this hedging strategy rarely offers a margin of over \$100 per head, it is proved most effective at limiting against negative shifts in margins.

Live cattle hedging, served as the intermediate strategy between cash and cattle crush hedging. Single commodity hedging offered the highest percentage of positive margins across the study period. This strategy also had a much higher mean margin than was displayed by cattle crush hedging. Therefore, it can be concluded the commodity futures market was much more apt to deliver positive margin during the feeding period rather than before. When live cattle hedging margins were positive, the range offered was typically between \$0 and \$150 per head. Single commodity hedging margins above this range were much more difficult to attain.

Between actual basis and expected basis, there were differences observed. Even though both basis methods result in similar trends expressed by each strategy, expected margin results were different. Margins calculated with expected basis tended to be lower than those determined

with actual basis. The level of variation also differed between hedging margins determined with actual and expected basis. Regardless of the hedging strategy, margins determined with expected basis had lower standard deviation. This meant the actual basis that occurred when physical transactions took place was riskier than expected, which highlights basis risk. When hedges are executed, a cattle feeder is reducing price risk, and increasing basis risk. One approach to further lowering basis risk observed in expected margins from both hedging strategies is using basis contracts. These contracts allow basis to become known, or secured, in advance of executing physical transactions.

For cattle feeders, this research suggests that there is no one optimal strategy that fits every environment that cattle feeders will face. Each strategy exhibited areas of strengths and weaknesses at various points in time across the study period. If a cattle feeder is solely concerned with reducing margin variation, then a hedging strategy should strongly be considered. The strategy chosen will depend on the desired level of risk reduction. Cattle feeders that have a negative outlook on the market may consider securing a tolerable margin using multiproduct hedging. If this strategy is too restrictive, then live cattle hedging can be implemented, as some protection is still offered against negative margins. If a cattle feeder expects positive market fundamentals and higher margins, then they may consider a less aggressive hedging strategy. Given these circumstances cash margins may be more lucrative as it allows all upside potential to be captured. However, if the level of risk tied to cash margins is troubling for cattle feeders, then live cattle hedging should again be considered. This strategy still allows margins to be secured, providing protection against downward shifts in cattle feeding margins. Live cattle hedging also offers more upside potential to be captured in comparison to cattle crush hedging.

By evaluating margins offered in the commodity futures markets, cattle feeders are providing themselves with a higher volume of margin opportunities. If an individual only takes what is offered to them in the cash market, they only have one margin opportunity on every turn of cattle. This one opportunity is extremely variable, and offers losses more times than it offers profits. Using hedging strategies to evaluate margin opportunities gives the producer a chance to attain improved margins and avoid significant losses. Another way to improve margins, suggested by results in this research, is to source high quality cattle. Advancing and protecting margins is important, especially as returns have lessened over time, while risk has increased substantially. This trend may continue, as the environment in which the cattle feeding sector operates is likely not going to become more certain.

Once a cattle feeder decides to evaluate expected margins through a hedging strategy, they must now make the decision of whether to secure the margin offered by the commodity futures market or wait. A cattle feeder should first consider what their goals are, in terms of margin levels and risk reduction. Then it is important to consider the seasonal patterns exhibited by cattle feeding margins. This can provide insight into whether margins may improve or worsen. A cattle feeder must account for fundamental factors observed in both input markets as well as the output market. An individual should evaluate previous futures and cash prices to determine the direction in which margins have been trending. Fundamental factors and previously offered margins can help in determining future directions of cattle feeding margins, and variation that may develop.

A specific limitation for this research was that yardage is included in all COG, PCOG, and ECOG calculations. This likely caused the overstatement of costs used in determining cattle feeding margins. Both expected and actual margins determined by this research may have been

lower than what was observed in practice. Future work to improve this research should include a method to model days on feed. In reality, feeding periods vary over the course of a year and across time. Being able to account for these differences would result in a more realistic scenario and allow the relationship between days on feed and cattle feeding margins to be examined. Extending this, modeling could also be used to better inform in weight and out weight expectations. Future research should examine a broader set of fundamental factors, and how they impact expected and actual cattle feeding margins. Finally, more work is necessary on improving basis estimation methods. Though historical averages are widely used, better basis estimation methods would assist in more accurately projecting margins into the future.

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APPENDIX A

APPENDIX A: ALTERNATE COG MODEL

Table 9A: Alternate COG Model

Residuals:

Min	1Q	Median	3Q	Max
-17.8072	-4.1709	-0.4821	4.5197	15.9414

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	20.11972	12.86467	1.564	0.120241
comlag	17.048	5.04639	3.378	0.000961 ***
comlagsqd	-0.57685	0.47197	-1.222	0.223826
Trend	0.06026	0.01515	3.976	0.000115 ***
KSFeb	2.26646	2.8169	0.805	0.422511
KSMar	1.9234	2.82085	0.682	0.496537
KSApr	1.05794	2.76632	0.382	0.702759
KSMay	-0.76555	2.76366	-0.277	0.782211
KSJun	-2.72196	2.81894	-0.966	0.336025
KSJul	-3.28245	2.81968	-1.164	0.24649
KSAug	-3.0181	2.81797	-1.071	0.28613
KSSep	-2.96298	2.81823	-1.051	0.295027
KSOct	-1.86429	2.82542	-0.66	0.510524
KSNov	-0.34014	2.85544	-0.119	0.905364
KSDec	-1.06676	2.83464	-0.376	0.707281

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.9 on 131 degrees of freedom

(3 observations deleted due to missingness)

Multiple R-squared: 0.814 Adjusted R-squared: 0.7942

F-statistic: 40.96 on 14 and 131 DF, p-value: < 2.2e-16

APPENDIX B

APPENDIX B: ALTERNATE BASIS ESTIMATIONS METHODS

$$\begin{aligned} \text{basis.5yr} = & \text{avg}(\text{basis.act}_{-1}, \text{basis.act}_{-2}, \text{basis.act}_{-3}, \\ & \text{basis.act}_{-4}, \text{basis.act}_{-5}) \end{aligned}$$

Equation 12A: Alternate Basis Estimate

$$\begin{aligned} \text{basis.5ytm} = & \text{trimmed.avg}(\text{basis.act}_{-1}, \text{basis.act}_{-2}, \text{basis.act}_{-3}, \\ & \text{basis.act}_{-4}, \text{basis.act}_{-5}) \end{aligned}$$

Equation 13A: Alternate Basis Estimate

APPENDIX C

APPENDIX C: OVERVIEW OF CRUSH MARGIN RESULTS FROM ALTERNATE MODEL

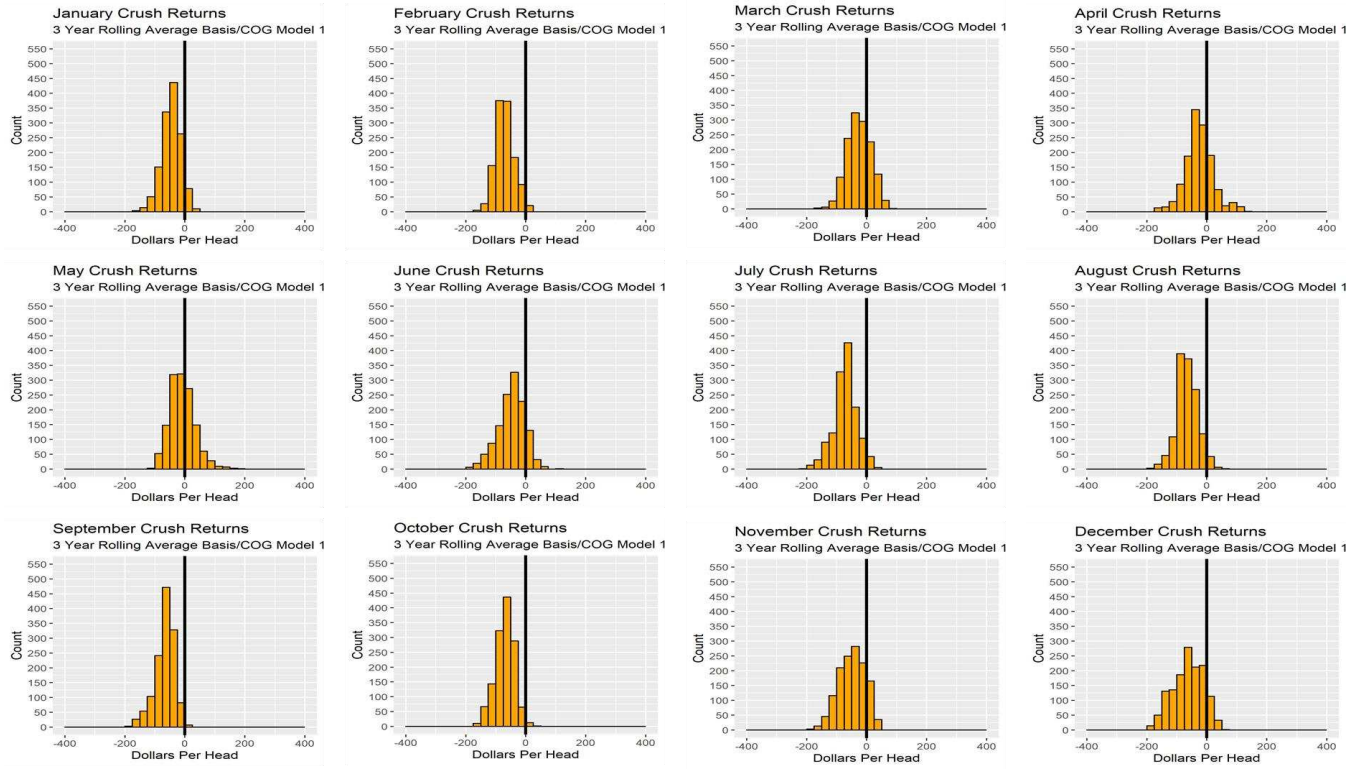


Figure 26C: Overview of Crush Margin Results from Alternate Model