THESIS

MEAN VARIANCE ANALYSIS OF WINTER WHEAT STOCKER CATTLE: DISTRIBUTION OF CASH, TRADITIONAL HEDGE, AND CALENDAR SPREAD GROSS MARGINS

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ABSTRACT

MEAN VARIANCE ANALYSIS OF WINTER WHEAT STOCKER CATTLE:
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CALENDAR SPREAD GROSS MARGINS

The purpose of this research is to evaluate historic returns for Oklahoma stocker cattle wheat pasture operations using cash and futures prices to determine potential risk management strategies that optimize returns and reduce risk. Returns are only evaluated for the stocker segment of dual-purpose winter wheat production. Producers face risk in a variety of forms; however, price risk and basis risk are the main interests of this analysis. The cash market for feeder cattle is subject to notable price volatility because of external market factors such as demand for feeder cattle from feedlot operations, changes in input prices like pasture and corn, availability of inputs, and feeder cattle supply levels. Price moves occur that impact the purchase cost and sale revenue of stocker operations that can result in unexpected financial losses. Risk management strategies have the potential to mitigate price risk associated with stocker cattle production.

Cash gross margins were evaluated for a variety of production scenarios that represent Oklahoma winter wheat production to develop a baseline for expected gross returns. The traditional hedge was evaluated over the 21-year period for each scenario to determine the influence of using basis adjusted futures prices to calculate a projected forward sale price, prior to the sale in the physical cash market. Calendar spread margins were calculated using basis adjusted futures prices for the appropriate futures contracts, purchase weight and sale weight of

each scenario for the summer to fall period prior to the purchase of cattle. Finally, cash, hedging, and spread returns were compared to determine how the three strategies impact gross margin returns and the variance of returns.

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CHAPTER 1: INTRODUCTION & OVERVIEW OF STOCKER CATTLE PRODUCTION

1.1 Background on Stocker Cattle Production

Stocker cattle production is a fundamental aspect of the beef supply chain that serves as a transition stage between cow-calf operations and feedlot producers. The term "stocker cattle" refers to 300 to 950-pound animals grazed on pastures after weaning. Stocker and feeder cattle are referred to interchangeably throughout this paper. The production of stocker cattle provides flexibility to the rate of feeder cattle placements in feedlots and is a critical component of consistency in the beef supply chain (Peel & & Riley, 2018). Furthermore, the stocker cattle segment allows producers to add weight to animals by grazing forage to capture the value of gain over the grazing period (Peel D. S., 2006).

Most cow-calf operations calve in the spring, leading to a larger supply of feeder calves to market in the fall after weaning (USDA E. R., 2021). Calves are either purchased for placement directly into a feedlot or enter a grazing operation with the intention of adding weight and frame to animals. Stocker operations are an essential component in spreading the supply of calves out over a longer duration of time throughout the year to accommodate fluctuating demand for placements into feedlots, constraints to total feedlot capacity, changes in input prices, and grazing availability.

There are a variety of production systems across the U.S., including pure stocker operators, cow-calf stocker operators, stocker and feedlot operators, and whole cycle operations (KSU Extension, 2021). Pure stocker operations are involved only in owning and backgrounding stocker cattle for the duration of the respective grazing period, while other stocker operators are simultaneously involved in multiple stages of cattle production (KSU Extension, 2021).

1.2 Problematic Situation

Feeder cattle prices are subject to notable price volatility, and seasonal trends expose market participants to cash price risk and potentially significant losses. Marketing cattle and managing risk is an area of particular importance to stocker producers who often face increased risk due to factors such as price volatility and narrow margins of cattle weight gain (Johnson, Doye, Lalman, Peel, & Raper, 2017). There is a fundamental price relationship between weight classes of feeder cattle that should allow for heavier cattle to be worth a higher value per head than lighter cattle (Peel D. S., 2006). However, there is no guarantee that profitable price levels will hold over the duration of the period from the purchase to sale of the cattle. Futures markets provide the opportunity to manage price risk using a directly or closely related futures contract for a given commodity. Feeder cattle futures contracts can be used to hedge price risk and potentially secure a profit margin prior to participation in the cash market. Survey response from Oklahoma stocker operators shows that 34 percent of producers indicate using futures contracts to offset feeder cattle price risk (Johnson, Doye, Lalman, Peel, & Raper, 2017).

A stocker producer may purchase calves at a time when the expected value of the heavier weight animal is higher than the actual realized value of that animal at the time of sale leading to a lower-than-expected return on a group of stocker cattle. Stocker calves are typically purchased with a particular expected margin that hinges upon the price paid for the animal, cost of gain, animal performance, and the price received at the time of sale (KSU Extension, 2021). Changes in the prices that impact the costs and revenue associated with that margin will have a direct impact on the profitability of stocker operators.

Feeder cattle prices are directly impacted by the overarching cattle cycle, fed cattle prices, corn prices, and weather conditions that impact the demand for placements and availability of grazing resources (Peel D. S., 2006). Changes in any of these factors, as well as unforeseen events can significantly impact the price received across weight classes and leave producers exposed to substantial price risk. Additionally, price volatility in commodity markets has increased over time (Karali & Power, 2013). This necessitates evaluation of risk management approaches to determine optimal production and risk management strategies for stocker operators to reduce the impact of price volatility. Figure 1 illustrates average prices for

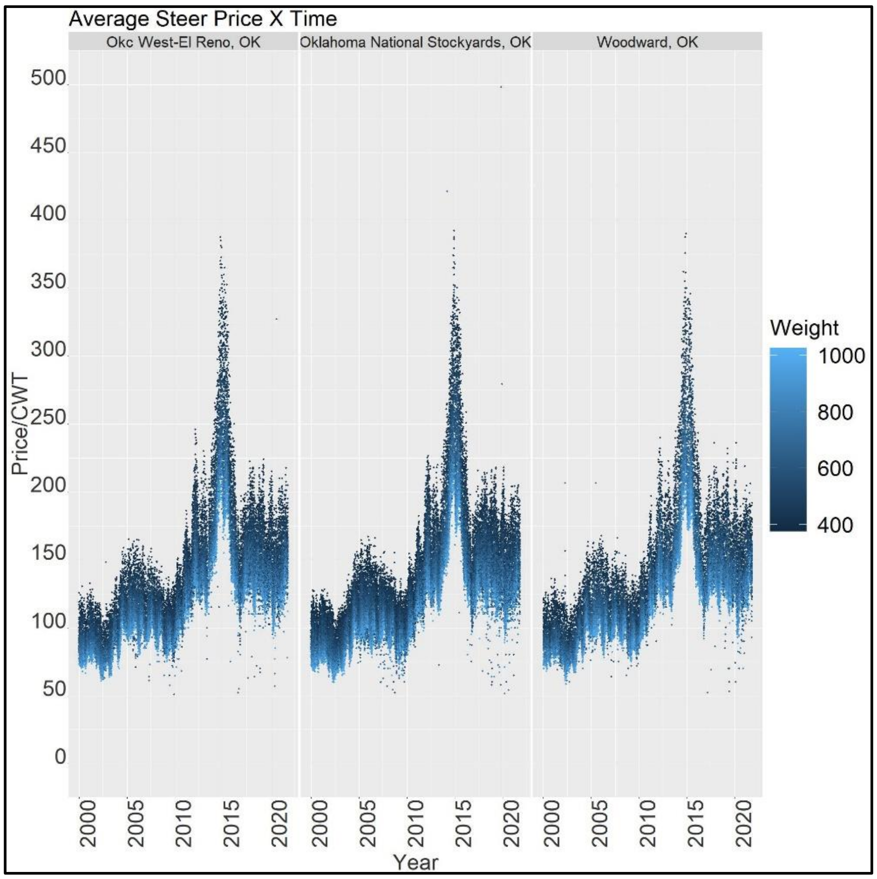

Figure 1: Average Steer Price from 2000 to 2021

lots of feeder steers of different weights over the last 21 years. The three sale barns exhibit similar price patterns across the time series, and prices have maintained higher levels in the period after 2010 than the prior decade with record prices occurring from 2014-2015.

Stocker production is a margin business, and profitable operations rely on efficient production decisions to generate revenue above costs. Stocker operators typically purchase calves in a weight range between 400 and 650 lbs. and adjust management practices depending on the quality of calves purchased (Peel D. S., 2006). Important considerations for stocker operators are purchase weight, consistency, expected average daily gain, pasture costs, forage quality, animal health, marketing method, the potential for value-added premiums or discounts, and sale weight (Peel & & Riley, 2018).

Additionally, the current age of stocker cattle operators is increasing; however, there will come a point when the sector begins to experience a generational turnover where younger operators are expected to enter the market or consolidation of existing firms will occur. Data from the 2021 National Stocker Survey shows 83% of respondents are 55 or older, compared to 60% in 2007. Furthermore, in 2020, 60% are 64 or older, compared to 32% in 2007 (KSU Extension, 2021). For context, the average age of agricultural producers in the 2017 USDA Census of Agriculture was 57.5. Younger producers may have limited access to capital relative to more established counterparts increasing the challenge of financial success in volatile markets. Another plausible demographic development could be that older individuals enter the market as more senior participants exit, and these individuals may or may not have any experience in stocker cattle production. Experience or fundamental knowledge of the financial component of stocker cattle production is an essential characteristic of stocker operations that exhibit long-term success. Research may be of interest to both experienced producers and participants that are newly entering the stocker segment as it aims to provide insight on multiple facets of Oklahoma winter wheat production that can enhance the marketing strategies of producers.

1.3 Objective of Study

The main objective of this study is to quantify and determine changes in gross margin returns by different marketing methods over time. This analysis focuses specifically on the Oklahoma pure stocker operator in a winter wheat scenario and assumes cattle of various weight classes will be purchased in the fall and sold in the early spring. Scenarios for this analysis include steer prices from the 400 to 950 lb. weight classes. Mean variance analysis is conducted for cash gross margin returns, basis adjusted futures gross margin hedge returns, and basis adjusted futures gross margin spread returns for a variety of production scenarios that include different purchase weight classes, purchase weeks, sale weeks, and amount of total gain over each potential winter wheat production year included in the analysis. The expected gross margin results in this analysis hinge upon the assumptions that animals are marketed in the designated week at the assumed weight and that animals perform as expected in terms of weight gain. Furthermore, this analysis assumes that it is feasible to both purchase cattle and graze cattle for the allotted duration in each year. However, there may be years included in this analysis with reduced volumes of cattle available during the purchase period or years in which grazing was not feasible due to drought. This analysis does not account for that possibility, but instead focuses on the price dynamics and basis environment that occurs in each of the 21 fall to spring production years.

This analysis is conducted to determine the average gross cash returns for a winter wheat stocker operation and the risk associated with the cash market. Additionally, risk management strategies using the feeder cattle futures contract are examined to determine when the futures market is offering a stocker operator a desirable hedging opportunity prior to cash marketing.

This analysis generates insight on potential risk management strategies for stocker cattle production on winter wheat pasture that can be adopted to reduce price risk for cattle producers, enhance margins, and reduce losses. The results of this analysis reveal how average gross margin returns to stocker cattle production in this scenario have changed over time and quantify differences between years, sale weights, and marketing strategies. Furthermore, this study examines market characteristics that inform decision-makers on feeder cattle basis relationships, and the tradeoffs between different marketing strategies. The effectiveness of using various historic basis types is assessed and a basis prediction model is identified and applied to improve the ability of predicting gross margin for the hedge strategy. The basis model is not applied to the spread strategy.

An additional objective of this research is to examine whether the average stocker operator could realistically stay in business solely marketing in cash markets. A producer must ask themselves the question, “Can my business survive periods of substantial negative returns without the use of risk management?” Moreover, it is also relevant to investigate under what market circumstances a producer should choose a more aggressive risk management approach to avoid the impacts of extreme negative price patterns due to increased market volatility. Finally, the analysis yields information that illustrates when a particular method is optimal to implement and describes market characteristics that occur when a marketing method is superior to its alternatives.

CHAPTER 2: PREVIOUS LITERATURE

The concept of using futures markets to hedge commodity production and reduce price risk is not novel to the cattle industry. Several studies have researched the implementation of hedging and the evaluation of profit and gross margin returns have historically examined the fed cattle sector using mean variance analysis with occasional assessment of the stocker sector. Mean variance analysis focuses on evaluating the average returns for a given activity over time and determines the distribution of those returns to calculate the variance or risk of generating the average return. Larger mean returns are intuitively more desirable; however, the relationship between average return and the variance or risk of achieving that return provides valuable knowledge when developing marketing and production strategies. An individual producer may be willing to accept a lower mean return if risk is sufficiently lower than a marketing method that offers a higher mean return. Conversely, a producer may prefer marketing methods that provide higher returns even with the presence of higher risk. The producer must decide their return and risk preferences.

Holland, Purcell, and Hague (1972) applied mean variance analysis of various hedging strategies to the feedlot sector using data from Kansas and New Mexico between 1965-1970. After constructing realistic hypothetical production scenarios, mean returns and variance of returns were generated for unhedged, completely hedged, seasonal hedging, and conditional hedging depending on expected forward price or expected net revenue (Holland, Purcell, & Hague, 1972). Holland et al. found that complete hedging using live cattle contracts to hedge the entire inventory of cattle a firm had on inventory resulted in the lowest variance of returns to cattle feeding in conjunction with the lowest mean returns. Moreover, some more selective hedging methods with simple decision rules decreased variance while offering higher potential mean returns relative to complete hedging; however, one alternative method also resulted in the largest variance of returns.

Schafer, Griffin, and Johnston applied integrated hedging to cattle feeding in 1978 by evaluating the use of live cattle, feeder cattle, and corn contracts to manage risk and improve returns to cattle feeding commonly known as the cattle crush hedging strategy. Schafer et al. (1978) found that price risk could be reduced with the implementation of integrated hedging of the core inputs and outputs of cattle feeding by taking long (buy) positions in feeder cattle and corn futures and a short (sell) position in live cattle futures simultaneously and then offsetting all these positions when physical feeder cattle and corn are purchased, and when physical live cattle are sold. Furthermore, the study found that returns could be improved in periods that the cash market alone was not profitable (Shafer, Griffen, & Johnston, 1978).

Leuthold and Mokler further demonstrated the increase in efficiency of returns through an integrated hedging approach relative to unhedged cash returns and output only hedging for the cattle feeding sector (Leuthold & Mokler, 1979). Using futures prices from 1972-1976 Leuthold and Mokler created 234 feeding periods and illustrated the potential opportunity of hedging in profit margins prior to the physical purchase of a commodity in the cash market. These studies significantly increased the flexibility of hedging programs by showing that industry participants have additional opportunities to protect profit margin and reduce risk. Positive expected profit margins could be achieved in every feeding period analyzed; however, the authors acknowledged the need for further analysis concerning basis risk, idle feedlot capacity, and the incorporation of reverse spreads (Leuthold & Mokler, 1979).

Initial analysis of hedging strategies using the feeder cattle futures contract to manage risk for Kentucky stocker cattle production conducted by Stephen L. O'Bryan, Barry W. Bobst and Joe T. Davis revealed that hedging could reduce the variance of returns for stocker cattle operations. The study noted that hedge revenue variance and length of hedge were inversely related (O'Bryan, Bobst, & Davis, 1977). However, O'Bryan et al. found that either short term hedging or not hedging generated higher mean returns. Furthermore, this analysis examined the feeder cattle futures contract during a period of its initial inception providing an interesting perspective on thinly traded futures markets that have been shown to exhibit downward bias. Downward bias may occur in markets with low volume and low open interest and may result in futures market prices underestimating cash prices (O'Bryan, Bobst, & Davis, 1977)

Russell and Dickey conducted a dual profit objective analysis for Oklahoma winter wheat, graze out, and summer grazing scenarios for stocker production. The study examined how establishing two mutually exclusive objectives, a minimum acceptable return and maximum permissible loss, impact average hedge returns to each of the production scenarios using prices from 1972-1981. The winter wheat scenario in this study assumed the producer purchased 74 head of 400 lb. stocker steers on November 15th of each year and sold the steers on March 15th at a weight of 565 lbs. The March feeder cattle futures contract was used to evaluate hedge opportunities for this scenario and served as the next to nearby contract to the time of cash sale. The study found that selective hedging increases the mean return and reduces the variance of returns relative to cash marketing and complete hedging (Russell & Dickey, 1983).

Anderson and Danthine developed the theory of cross hedging commodities that do not have a true underlying futures contract. When a futures contract does not exist for the specific commodity that is being hedged, a related futures contract can be used instead. This is relevant for the hedging of feeder cattle that are outside the weight range specified in the feeder cattle futures contract which is written for an 800 lb. steer.

Jenkins, Carver, and Menkhaus applied gross margin mean variance analysis to Wyoming stocker cattle summer grazing scenario with four marketing scenarios. For the years 1974-1984, there were an average 21.5-26.7 weeks per year in which gross income from the sale of feeder steers could have been increased by hedging, depending upon the marketing period used, relative to cash returns alone for a 600 lb. to 700 lb. steer marketed at the Torrington Wyoming Auction Barn (Jenkins, Carver, & Menkaus, 1986). The analysis found that short hedges placed in the spring using the fall feeder cattle contracts tended to be the most profitable over the summer grazing scenario and period analyzed. The study only examined how revenue could be enhanced by placing a hedge and did not include the purchase cost in the analysis. It assumed the average cash price was calculated using a seven-week average from mid-August to early October for steers in one weight class as well as three subsets from the seven-week period (Jenkins, Carver, & Menkaus, 1986).

Additionally, Jenkins et al. showed that using a three-year simple average basis generates the most accurate forecasts for feeder cattle basis during the period analyzed (1986). Basis is the difference between cash price and futures price and can either be positive or negative (Purcell & Koontz, 1999). Basis is partially a function of difference in local supply and demand conditions between regions, transportation, and storage costs (Purcell & Koontz, 1999). When a hedge is placed, a basis estimate is necessary to add to the futures price to determine the forward price which is used as the expected cash price. The forward price can be used to estimate the expect purchase or sale price of a commodity prior to the cash purchase or sale (Purcell & Koontz, 1999).

McCollum, Carver, and Menkhaus revisited the Wyoming summer grazing scenario to examine mean gross margin and variance for cash, futures, and options trades using Torrington auction prices and CME futures and options prices. The scenario included data from 1976-1987 with the assumption that steers were purchased in a six-week period from February 15th to March 31st at an average weight of 500 lbs. and sold over a seven-week period from August 15th to October 7th producing a total of 300 lbs. of gain with a final sale weight of 800 lbs. Prices used in the study were weekly average cash prices and close prices for futures and options (McCollum, Carver, & Menkhaus, 1989). The study examined gross returns on 39 separate marketing strategies using standard mean variance evaluation criteria and mean minus one as a decision rule for ambiguous strategies and found a fence options strategy, short hedge, or long/short combination hedge to be the superior strategies relative to the cash market.

Epplin, Krenzer, and Horn conducted a long-term analysis of net returns for dual purpose wheat and grain only wheat production from 1980 – 1999 to quantify and compare the returns from each sector for Garfield County, Oklahoma. The production systems were differentiated by wheat planting date, stocking rate, and days of grazing (Epplin, Krenzer, & Horn, 2001). Costs were estimated using historical USDA wheat costs while stocker costs were based upon a 1999 enterprise budget adjusted using the USDA farm price index to generate nominal cost for previous years (Epplin, Krenzer, & Horn, 2001). The study found that dual-purpose production generated higher returns than the grain only scenario in 16 of the 20 production years.

This analysis seeks to build upon previous mean variance studies by expanding the matrix of scenarios evaluated to include multiple purchase weights, amounts of gain, and marketing windows for a total of 288 individual hypothetical cash scenarios for each of the 21 production years for a total of 6048 cash gross margin returns. The combination of four purchase weeks and four sale weeks are evaluated to prevent the purchase or sale price in any one week to from exerting undue influence on gross margin returns. Additionally, the hedge analysis examines the effectiveness of using various basis calculations to determine when the March or April feeder cattle futures contracts are pricing in favorable gross margins after the purchase and before the physical sale of feeder cattle. Furthermore, spread returns are calculated to determine if futures price in a hedgable return, prior to both the purchase and sale of physical cattle by basis adjusting November feeder futures with the corresponding basis for the assumed purchase weight and adjusting either the March or April futures with the corresponding basis for the assumed sale weight of each scenario

The goal of this analysis is to develop a more comprehensive understanding of gross margin returns for the Oklahoma winter wheat scenario and risk management strategies that can be used to protect or enhance gross margin. Mean variance gross margin analysis has been shown to be an effective method for evaluating fed cattle and feeder cattle markets alike. However, previous studies have not analyzed the contemporary market dynamics of Oklahoma winter wheat production. Furthermore, a basis model is identified and applied to the hedge return scenario to improve actual basis and hedge gross margin predictions relative to using historic basis estimates.

Although price levels and basis relationships may differ between regions, the change in price volatility that has occurred in recent years does not have an isolated impact to the location analyzed in this scenario. Therefore, the fundamental setup, results, and implications of this research may provide insight and guidance to similar studies examining other locations and grazing scenarios.

CHAPTER 3: DATA

To calculate gross margin returns for cash, hedge, and spread trades historic price data were needed to quantify the average prices that correspond to the purchase weight and sale weights of steers on the marketing dates included in this analysis to calculate purchase cost and sale revenue. The period analyzed ranged from 2000 to 2021 and included cash and futures price information. This analysis used data available from three sources: USDA feeder cattle auction prices, CME futures prices for feeder cattle and corn, and NCAR Palmer Drought Severity Index values. Additionally, a constructed scenario matrix with the corresponding time and weight scenarios that align with Oklahoma dual purpose winter wheat production served two purposes. The first was to capture the variability in production practices in terms of the range of purchase weights, amount of gain, and marketing weeks indicative of the production scenario. Second, it served as the coordinate system to gather prices from the auction and futures data. In addition to the feeder cattle price data, March corn futures price and the Palmer Drought Severity Index values were used in the basis estimation model. The following subsections describe data manipulations necessary to conduct the analysis.

3.1 USDA Price Data

The cash price data was drawn from USDA reports that include reported prices for four classes of cattle: Steers, Heifers, Bulls, and Dairy Steers from 2000 to 2021. States represented in the main dataset include Kansas, Nebraska, Oklahoma, Wyoming, and Missouri. The data in this analysis only included lots of steers sold in Oklahoma.

USDA price data was obtained primarily from the USDA Feeder & Replacement report from 2000 to 2019. In 2019, the USDA changed its reporting method, and the reports were divided into LSD_MARS_1280, LSD_MARS_1281, LSD_MARS_1828. The primary data include Entry Date, Region (State), Location (Auction), Commodity, Commodity Class (Steers, Heifers, Bulls, Dairy Steers), Feeder Cattle Grade, Head, Prices (low, high, and weighted average), Weights (low, high, weighted average), and Comments.

3.2 Subsets of USDA Price Data:

Upon initial data evaluation, there were prices in the dataset that were unrealistic and were likely a result of recording error or sale prices being expressed on a per head basis rather than a per hundredweight basis. Figure 2 illustrates auction barn prices for Oklahoma by sale

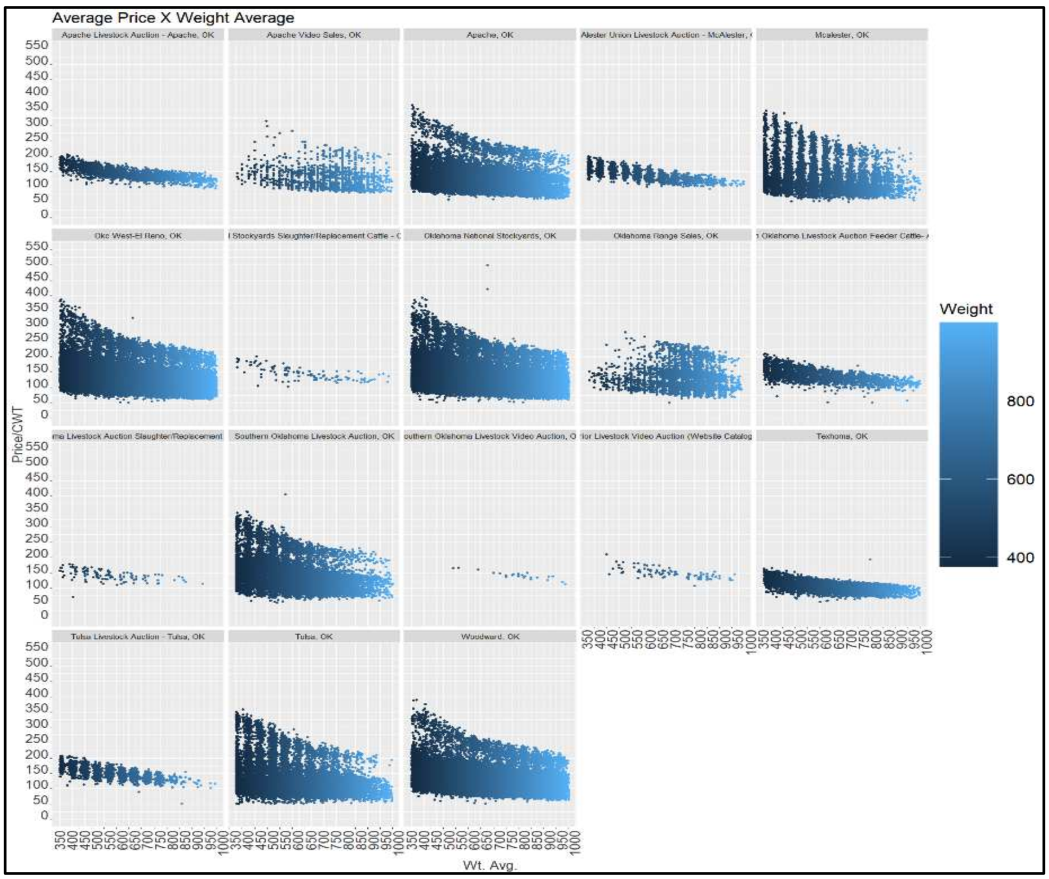

Figure 2: Oklahoma Sale Barn Steer Prices by weight. Price/cwt. decreases nonlinearly as weight increases.

weight. The three sale barns selected in this analysis are Oklahoma City, Woodward, and El Reno. Each point represents a lot of steers sold over the 21-year period.

1) The comments section was used to remove any prices that were designated as per head, bred, or replacement.

2) Prices were further sorted where lots that were less than $500/cwt and greater than $50/cwt remained.

3) Furthermore, weight was sorted to include only lots that were greater than 375 lbs. and less than 976 lbs. to include lots that fall into the weight categories of interest for this analysis.

4) The data was subset by commodity class and location to evaluate prices for steers sold in OKC National Stockyard, Woodward, Oklahoma, and El Reno, Oklahoma.

Table 1 summarizes the main components of the auction price data used in this analysis and reports summary statistics by weight class of all the lots of cattle that were included in the analysis. Oklahoma National Stockyards contains the highest percentage of lots in each weight class, followed by OKC West - El Reno, while Woodward contains the lowest percentage of lots in each weight class. N represents that number of lots that fall into a particular weight class and not the number of head that were sold in that weight class. The greatest number of were in the 650-pound weight class and the fewest number of were in the 950-pound weight class. Price per hundredweight is shown to decrease nonlinearly at a decreasing rate as weight increases. Standard deviation is highest for lighter weight class and decreases as weight increases. Once the data were filtered to include the desired location, sex, and average weight of the sale lots, variables were generated from the data to facilitate analysis. The first created variables were ISO Week and ISO Year using the Entry Date column. ISO Year is the year in which the cattle were sold. ISO Week is a date system that aligns weeks across years which aids in long term time series analysis (Kuhn, n.d.).

Table 1: Summary Statistics of Sale Barn Data

	Oklahoma Auction Barn Data												
	400	**450**	**500**	**550**	**600**	**650**	**700**	**750**	**800**	**850**	**900**	**950**	**Total (N=122912)**
Location	(N= 6941)	(N= 8971)	(N= 10558)	(N= 11672)	(N= 13124)	(N= 13356)	(N= 13118)	(N= 11979)	(N= 10854)	(N= 9376)	(N= 7538)	(N= 5425)	
El Reno	2356 (33.9%)	2946 (32.8%)	3548 (33.6%)	3753 (32.2%)	4179 (31.8%)	4265 (31.9%)	4226 (32.2%)	3761 (31.4%)	3377 (31.1%)	2948 (31.4%)	2405 (31.9%)	1680 (31.0%)	39444 (32.1%)
Oklahoma National Stockyards	2907 (41.9%)	3943 (44.0%)	4798 (45.4%)	5345 (45.8%)	6117 (46.6%)	6012 (45.0%)	5732 (43.7%)	5107 (42.6%)	4414 (40.7%)	3680 (39.2%)	2893 (38.4%)	2112 (38.9%)	53060 (43.2%)
Woodward	1678 (24.2%)	2082 (23.2%)	2212 (21.0%)	2574 (22.1%)	2828 (21.5%)	3079 (23.1%)	3160 (24.1%)	3111 (26.0%)	3063 (28.2%)	2748 (29.3%)	2240 (29.7%)	1633 (30.1%)	30408 (24.7%)
Average Weight	**Pounds**												
N	6941	8971	10558	11672	13124	13356	13118	11979	10854	9376	7538	5425	122912
Mean	**402.36**	**451.40**	**501.67**	**551.30**	**601.80**	**651.21**	**701.11**	**750.80**	**800.95**	**851.65**	**901.10**	**950.60**	**667.05**
SD	16.02	16.63	16.63	16.98	16.91	17.02	17.10	17.39	17.39	17.02	16.51	16.11	153.75
Min	376	426	476	526	576	626	676	726	776	826	876	926	376
Max	425	475	525	575	625	675	725	775	825	875	925	975	975
Average Price	**Price Per Hundredweight**												
N	6941	8971	10558	11672	13124	13356	13118	11979	10854	9376	7538	5425	122912
Mean	**159.76**	**152.38**	**143.46**	**137.53**	**132.32**	**128.65**	**124.59**	**122.61**	**119.93**	**119.08**	**117.16**	**115.20**	**130.83**
SD	50.48	47.17	42.24	40.37	38.20	36.36	35.11	34.28	33.40	32.94	31.87	31.27	40.01
Min	60	52	58	58	52	51	60	54.5	51.5	58.5	59.75	60.65	51
Max	392	387	333	306	296	327	498	254	260	238	228	223	498
Price	**Per Head**												
N	6941	8971	10558	11672	13124	13356	13118	11979	10854	9376	7538	5425	122912
Mean	**642.46**	**687.35**	**719.28**	**757.83**	**796.20**	**837.61**	**873.37**	**920.57**	**960.57**	**1013.95**	**1055.65**	**1095.03**	**854.41**
SD	203.39	212.47	211.67	222.34	230.60	236.99	246.57	258.38	268.35	280.69	287.41	297.82	275.96
Min	245	246	292	325	319	330	425	408	422	488	548	590	245
Max	1632	1668	1641	1692	1746	2172	3367	1907	2023	2026	2052	2129	3367

The ISO week system defines the ordinal weeks that occur each year. Most years have 52 weeks however, the ISO week system also accounts for years that have 53 weeks. Using ISO weeks was essential for this analysis to standardize the weeks across all years included in the time series for both the price data and the scenario matrix. In the scenario matrix, purchase weeks were established so that purchase prices for each purchase weight were evaluated in the 43rd, 44th, 45th, and 46th week of each year. These ISO weeks align with approximately the last two weeks in October, and the first two weeks in November. Additionally, sale prices for each sale weight were evaluated in the 9th, 10th, 11th, and 12th week of each year. These ISO weeks align with approximately the last two weeks in February, and the first two weeks in March. The calendar date changes year over year; however, the price occurs in the same numerical ISO week of each year.

Next a weight class variable was created that designated each lot into a weight class. Weight classes were determined by 50 lb. intervals from the average weight listed for each lot of cattle outlined in Table 2.

Table 2: Weight Class Parameters

Weight Class (lbs.)	Weight Range (lbs.)
400	376-425
450	426-475
500	476-525
550	526-575
600	576-625
650	626-675
700	676-725
750	726-775
800	776-825
850	826-875
900	876-925
950	926-975

Assigning each lot to a weight class allowed for the aggregation of prices for each weight class. This process also aided in the analysis by allowing weight classes to be examined individually.

After each lot was categorized by an appropriate weight class, ISO week, ISO year, the weight class variable, average price, and lot volume were used to calculate the volume weighted weekly average price for each weight class. Aggregate prices were weighted by the number of head in every lot of cattle that were sold in the same weight class in the same ISO week and ISO year. The calculated average price aggregated the daily sale prices from the three sale barns. If no lots of cattle were sold in a particular weight class in each week, then no average cash price was reported or included in the dataset. This occurred most frequently in lots that were in the 400 lb. weight class or 950 lb. weight class and during holidays. However, because the cash price and basis information used in this analysis occur during periods of high volume the missing values did not impact the results of this study.

3.3 Futures Data

To calculate feeder cattle basis and projected gross margin returns for both the hedge and spread scenario, historic CME futures contract data was acquired from Cattlefax and included daily futures prices for all feeder cattle contracts from 2000 to 2021. For this analysis, only data for the March, April, and November feeder cattle contracts were used. The March and April contracts correspond to the sale weeks of all feeder cattle in the hedge and spread scenario. The March futures contract was selected as it is the nearby contract to the physical sale of cattle in the cash market while the April futures contract serves as the next to nearby contract. The nearby futures contract and next to nearby contract are used because these contracts express the highest correlation to a commodities cash market (Purcell & Koontz, 1999). The November contract corresponds to the purchase weeks in the spread scenario serving as the nearby contract. The November feeder cattle futures were basis adjusted to calculate forward purchase price based upon the purchase weight of each observation. Only the nearby contract to the cash purchase was evaluated. In the spread return analysis, the basis adjusted March and April feeder cattle futures prices were used for forward sale price calculations based upon the sale weight of each observation.

Daily futures data included the following variables, Entry Date, Iso Week, Iso Year, Week Ending Date, Commodity Pit Symbol, Commodity, Contract Year, Contract Month, Contract Week, Contract Day, Open Price, High Price, Low Price, Close Price, Open Interest, Volume, Contract Expiration, Futures Type, Max Date, and Max Year.

Daily futures close prices were averaged to generate the weekly average futures price for each contract. Weekly average was used to simplify the analysis and mitigate intraweek price changes that would result in a producer placing a hedge or spread in a week with significant change between the start of the week and the end of the week close price. Using the average close price on a weekly basis standardizes the prices used to determine what the average hedger would have received as a forward return.

3.4 Cash Scenario Matrix

Production scenarios were constructed to align with the timing, purchase weights, performance, and sale weights realistic of Oklahoma winter wheat programs. Timing of placements included the fall purchase of steer calves in approximately the last two weeks of October and first two weeks of November corresponding to ISO weeks 43, 44, 45, and 46. The four purchase weeks were assigned to each purchase year from 2000 to 2020. Expected sale weeks included the last two weeks of February and the first two weeks of March corresponding to ISO weeks 9, 10, 11, and 12. The four sale weeks were assigned to each sale year from 2001 to 2021.

ISO week 12 is used as it aligns most consistently with the week March 15th. This week is selected to accommodate dual purpose wheat production and an approximate removal of stocker cattle from wheat pasture. March 15th has been identified as a common production decision point in dual purpose winter wheat production when cattle must be sold or grazed out for a longer duration (DeVuyst, Epplin, Taylor, Horn, & Edwards, 2011). For a wheat crop to be harvested, cattle must be removed from wheat pasture to allow sufficient time for regrowth of the wheat prior to the occurrence of first hollow stem (DeVuyst, Epplin, Taylor, Horn, & Edwards, 2011). Wheat pasture that is grazed past the occurrence of first hollow stem has been shown to have negative impacts on yield which results in reduced crop production (Epplin, Krenzer, & Horn, 2001). This analysis did not include graze out cattle that are grazed on wheat pasture past the point of first hallow stem and sold later in the year.

There was a total of 16 potential marketing windows derived from the combination of the four purchase weeks and four sale weeks in a production year. In this analysis, a producer had the option to purchase cattle in the first purchase week and market cattle in any of the four sale weeks, purchase in the second purchase week and market cattle in any of the four sale weeks, purchase in the third purchase week and market cattle in any of the four sale weeks, or purchase in the fourth purchase week, and market cattle in any of the four sale weeks. These 16 marketing windows were evaluated across the 21-year period. Each marketing window spans from the fall of one year, to the spring of the next year and is referred to as the production year. The first production year in the analysis spanned 2000-2001 and the final production year included 2020-2021. The 16 combinations of purchase and sale weeks were evaluated for each production year.

Multiple purchase weights were evaluated for each marketing window. Purchase weights included lots weighing 400 lbs., 450 lbs., 500 lbs., 550 lbs., 600 lbs., and 650 lbs. Three amounts of total gain were evaluated for each purchase weight. For example, a lot that was purchased at 400 lbs. in week 9 and sold in week 43 included an observation of that marketing scenario where gain was evaluated at 200, 250, and 300 lbs. for each production year. Differences in gain for the same marketing window generated a higher sale weight, a different sale price, and different gross margin. This was done to evaluate how revenue changed with different amounts of total gain. The three amounts of gain were selected to generate realistic variance in performance across the time frame for each potential marketing window and purchase weight.

The gain amount variable was added to the purchase weight of each scenario to generate the sale weight. For each year, the 16 unique marketing windows, 6 purchase weights, and 3 amounts of gain generate 288 unique scenarios that were plausible for a total of 6048 observations across the entire period analyzed. This scenario matrix served as the fundamental component to calculate gross margin cash returns and forward hedge returns.

To finalize the scenario matrix, purchase price, and sale price were acquired from the USDA Feeder Cattle Price data. The purchase price was drawn from the calculated weekly average price that corresponds to each observation’s purchase weight class in the week and year of an observation’s purchase week. The sale price was the weekly average price of each production scenario’s sale weight class in the week and year of an observation’s sale week.

Table 3 presents summary statistics of the constructed scenario matrix. 6048 total observations were split evenly between the three amounts of gain. Note that sale weights differed slightly by total amount of gain. The other components of the scenario matrix are identical. Table 4 illustrates the hypothetical performance of cattle by sale weight. Not all sale weights exhibit the same amount of gain leading to differences in the number of observations for the 600 lb., 650 lb., 900 lb., and 950 lb. weight classes. All sale weights are evaluated for the same period of grazing. The number of observations and range in average daily gain also varies between sale weights. Table 4 illustrates the hypothetical cattle performance of each sale weight class included in this analysis. Amounts of gain are varied between sale weights but not purchase weights. The hypothetical cattle performance aligns with previous studies expected average performance (Peel D. S., 2006).

Table 3: Scenario Matrix

	200 (N=2016)	250 (N=2016)	300 (N=2016)	Total (N=6048)	p value
Purchase Week					1.000
N	2016	2016	2016	6048	
Mean	44.500	44.500	44.500	44.500	
SD	1.118	1.118	1.118	1.118	
Min	43	43	43	43	
Max	46	46	46	46	
Sale Week					1.000
N	2016	2016	2016	6048	
Mean	10.500	10.500	10.500	10.500	
SD	1.118	1.118	1.118	1.118	
Min	9	9	9	9	
Max	12	12	12	12	
Purchase Year					1.000
N	2016	2016	2016	6048	
Mean	2010	2010	2010	2010	
SD	6.057	6.057	6.057	6.056	
Min	2000	2000	2000	2000	
Max	2020	2020	2020	2020	
Sale Year					1.000
N	2016	2016	2016	6048	
Mean	2011	2011	2011	2011	
SD	6.057	6.057	6.057	6.056	
Min	2001	2001	2001	2001	
Max	2021	2021	2021	2021	
Purchase Weight					1.000
N	2016	2016	2016	6048	
Mean	525.000	525.000	525.000	525	
SD	85.412	85.412	85.412	85.398	
Min	400	400	400	400	
Max	650	650	650	650	
Sale Weight					< 0.001
N	2016	2016	2016	6048	
Mean	725.000	775.000	825.000	775	
SD	85.412	85.412	85.412	94.656	
Min	600	650	700	600	
Max	850	900	950	950	

Table 4: Hypothetical Cattle Performance

	600 (N=336)	650 (N=672)	700 (N=1008)	750 (N=1008)	800 (N=1008)	850 (N=1008)	900 (N=672)	950 (N=336)	Total (N=6048)	p value
Gain										< 0.001
N	336	672	1008	1008	1008	1008	672	336	6048	
Mean	200.000	225.000	250.000	250.000	250.000	250.000	275.000	300.000	250.000	
SD	0.000	25.019	40.845	40.845	40.845	40.845	25.019	0.000	40.828	
Min	200.000	200.000	200.000	200.000	200.000	200.000	250.000	300.000	200.000	
Max	200.000	250.000	300.000	300.000	300.000	300.000	300.000	300.000	300.000	
Period										1.000
N	336	672	1008	1008	1008	1008	672	336	6048	
Mean	127.333	127.333	127.333	127.333	127.333	127.333	127.333	127.333	127.333	
SD	11.421	11.413	11.410	11.410	11.410	11.410	11.413	11.421	11.405	
Min	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	
Max	154.000	154.000	154.000	154.000	154.000	154.000	154.000	154.000	154.000	
ADG										< 0.001
N	336	672	1008	1008	1008	1008	672	336	6048	
Mean	1.590	1.788	1.985	1.985	1.985	1.985	2.183	2.380	1.985	
SD	0.149	0.256	0.374	0.374	0.374	0.374	0.284	0.231	0.373	
Min	1.300	1.300	1.300	1.300	1.300	1.300	1.600	1.900	1.300	
Max	1.900	2.400	2.900	2.900	2.900	2.900	2.900	2.900	2.900	

3.5 Hedge Scenario Matrix

The 6048-observation cash scenario matrix served as the base for the hedge scenario matrix. For each marketing scenario, there was a duration between the week cattle were purchased until the week cattle were sold. This duration is the interval of potential weeks a hedge could have been placed by selling a March or April futures contract. The number of hedging week opportunities between individual scenarios was dependent on the purchase week and sale week in that observation. Observations with the purchase week equal to ISO week 43 and the sale week equal to ISO week 12 had the largest interval of weeks to place a hedge, while observations with the purchase week equal to ISO week 46 and sale week equal to ISO week 9 had the smallest interval of weeks to place a hedge.

The weekly average futures price for each week from the week of purchase until the week of sale represented the potential futures hedge price. This price was adjusted using the appropriate basis for each observation's sale weight to calculate the expected forward price. Basis values in this analysis were calculated for the actual basis, 3-year average basis, 5-year average basis, and 5-year Olympic average basis. The actual basis and historic basis estimates were the closing basis. Closing basis is the difference between the cash price and the futures price at the time a physical commodity is marketed. In this analysis closing basis was dependent on the sale year, sale week, and sale weight of each observation. Every observation was evaluated using the March feeder cattle futures contract and the April feeder cattle futures contract prices.

For example, the actual March basis for an observation with a sale year of 2021, sale week of 12, and sale weight of 700 lbs. was the average cash price of a 700 lb. steer minus the average March futures close price for the same year and week. The 3-year average basis was the average of the actual basis that occurred in the three previous years, in this case 2020, 2019, 2018, for the same weight class and sale week. The 5-year average basis was the average of the actual basis that occurred in the five previous years, in this case 2020, 2019, 2018, 2017, 2016 for the same weight class and sale week. The Olympic average basis was the average of the actual basis that occurred in the five previous years, in this case 2020, 2019, 2018, 2017, 2016, with the single highest historic actual basis, and the single lowest historic actual basis excluded, for the same weight class and sale week.

The basis adjusted futures price acted as the forward price on the cattle and changed weekly as the weekly average futures price changed. The basis value that was added to the futures does not change within a production year. For example, if the actual basis for 650 lbs. steer sold in ISO week 12 of 2021 was $10.00, that basis number was added to the weekly average futures price starting in the first week a hedge could be placed in the fall of 2020 until the end of the potential hedge interval. The end of the hedge interval as equal to the cash sale week of each observation. Forward gross margin was calculated for each hedge week in an observation by multiplying the forward price by the sale weight and subtracting the cost of purchasing a steer at the price that corresponds to the purchase weight and purchase week of the underlying cash scenario observation.

Actual basis in the current production year is never known to the hedger until the time cattle are sold in the cash market. Nevertheless, actual basis served as an important baseline to gauge the effectiveness of the other basis methods as estimates of actual basis. Using actual basis was informative to determine the true forward price the futures market offered historically. Forward prices were generated using each of the four basis methods, and gross margins were calculated for each respective basis method. Estimated forward gross margin vary between the different basis methods, which is attributed to basis risk also known as basis error. Basis risk is the difference between the expected basis used when placing a hedge and the actual basis realized when a hedge was lifted.

3.6 Spread Scenario Matrix

The spread analysis was similar to the hedge analysis as basis was used to adjust futures prices to forward prices. In the spread scenario, no cash cattle have been purchased, but it is assumed cattle will be purchased and sold at the weights that correspond to each cash market observation. The spread evaluated the prospect of hedging both the purchase and sale of an animal by basis adjusting the futures price of the November feeder cattle contract, and the March or April feeder cattle contract before the cattle are purchased in each production year.

The forward purchase price was calculated by basis adjusting the weekly average November feeder cattle close price to the appropriate purchase weight of a given scenario. The forward sale price was calculated by basis adjusting the weekly average futures close price of either the March or April feeder cattle contract in each of the weeks leading up to the physical purchase of the desired weight class. The forward adjusted purchase price was multiplied by the purchase weight to generate forward cost and the forward adjusted sale price was multiplied by the sale weight to generate the forward revenue. The difference between the forward revenue and the forward cost is the estimated gross margin the futures market is offering at a given point in time. The spread could be evaluated from the time the spring contracts have sufficient volume, until the physical purchase of cattle in the cash market at which time the purchase cost becomes known and only the output can be hedged.

In this study, the spread margin evaluation began in ISO week 22 of each purchase year which aligned approximately with the first week of June and ended in the ISO week that cattle are purchased in the cash market for each observation. The spread scenario built upon the framework of the cash scenario in the sense that the final spread date was executed in ISO week 43, 44, 45, or 46. For example, when cattle were purchased in ISO week 43, the last week the spread was evaluated was ISO week 43. For reference, ISO week 46 aligns approximately with the second week of November. After the physical purchase of a weight class of feeder steers, the purchase cost was known, and the purchase could no longer be hedged.

3.7 Basis Model Data

Feeder cattle basis was calculated for each weight class using the weekly average cash price and the weekly average futures price. The March corn futures contract was selected for the basis model. March corn futures serve as the nearby corn price to the placement of cattle in this analysis. Weekly average prices were calculated for the March contract. Additionally, the Palmer

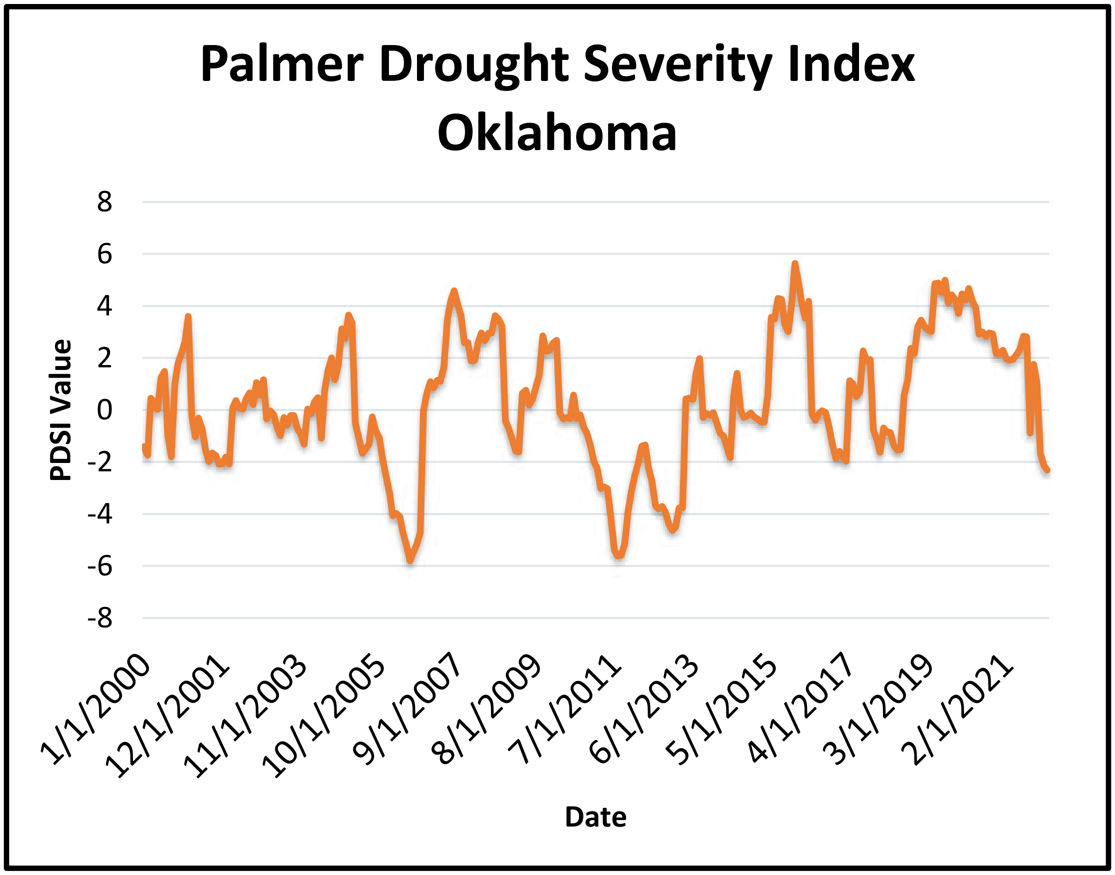

Figure 3: Palmer Drought Severity Index Oklahoma

drought severity index was used in the basis model regression. Figure 3 shows values reported monthly for the state of Oklahoma over the last 21-years. Negative values of the PDSI index indicate more severe drought conditions.

CHAPTER 4: METHODS

4.1 Cash Gross Margin

Gross margin is an economic measure of the difference of the value of the animal at the end of the grazing period relative to the beginning of the grazing period. Gross margin was calculated by subtracting the value per head at purchase from the value per head at the time of sale for each observation in the cash scenario matrix. Gross margin represents the increase in the total value of the animal over the grazing period. Stocker profitability is primarily determined by the gross margin value (Peel D. S., 2006). Due to its influence on profitability, gross margin serves as an essential metric for measuring average returns for the stocker sector. The gross margin calculation includes the cost and revenue associated with the purchase and sale and does not include other costs that are incurred during the stocker grazing period such as feed and forage, supplement, interest, marketing cost, veterinary and medical costs, death loss, shipping, or labor and equipment. However, the purchase cost of the animal in stocker production makes up 75-85% of the cost associated with stocker cattle production (Peel D. S., 2006). Therefore, gross margin captures most of the total cost associated with stocker cattle production.

Additional costs may vary for different producers and are also related to differences in performance between weight classes of stocker cattle. For instance, an individual producer may purchase a set of younger higher risk cattle that are of lower quality and require more input costs in terms of nutrition or health versus a producer that purchases cattle that are ready to graze. Moreover, pasture leases are written with a variety of payment agreements making it difficult to determine which is most appropriate for generic analysis. A lease may be on a per acre, per head, or per pound of gain however, this list is not all inclusive and only exhibits the most common forms of lease agreements (Peel D. S., 2006). Costs for individual producers vary and using gross margin to evaluate returns facilitates more effective comparison between years and different scenarios within the analysis.

The following example articulates the gross margin calculation. If a stocker operator purchased a group of 400 lbs. calves at a price of $175/cwt (hundredweight equal to $1.75/lb.) and then sold at the end of the grazing period at a weight of 600 lbs. and a price of $150/cwt the gross margin is calculated as follows.

Cash Gross Margin: (SW*SP)/100 - (PW*PP)/100 = CGM
Cash Gross Margin: (600*150)/100 – (400*175)/100 = $200/head

Equation 1: Cash Gross Margin Calculation

Where SW is the sale weight, SP is the average sale price per hundredweight for the corresponding weight class SW during the sale week, PW is the purchase weight, PP is the average purchase price per hundredweight for the corresponding weight class PW during the purchase week, and CGM is the estimated cash gross margin.

Each production scenario corresponds to a particular purchase and sale week, and purchase and sale weight class of cattle. The purchase price was derived from each purchase year, purchase week, and purchase weight. These served as the coordinates that identify the average price from the sale barn data for a particular time and weight class. Similarly, sale price was generated by sale year, sale week, and sale weight from each scenario. Together, the price data alongside the weight information was used to generate the cash gross margin for each production scenario across the time series.

The cash returns matrix was evaluated in totality then subset by sale year, amount of gain, purchase weight, and sale weight to facilitate more comprehensive analysis. Average gross margin was calculated for each sale year over the entire period. Average gross margin was calculated for each purchase weight and sale weight class over the entire period.

Assessing gross margin returns by various factors provided insight upon changes in the overall market and how producers were impacted by price changes and market dynamics that shift with the cattle cycle, grazing availability, and marketing leverage. Changes in market factors, such as cow herd expansion and contraction, changes in input prices in the feedlot sector, volume of cattle available, demand for placements, or extensive droughts provide motivation for determining the optimal strategy for managing price risk that occurs in the stocker cattle segment.

4.2 Basis

To calculate expected margins using futures prices, it was necessary to assemble historic basis information specific to the weight classes, and marketing dates included in the analysis. Basis was calculated by using the weekly average cash price for each weight class and the weekly average futures price at the time of sale. This yielded the actual closing basis for each weight class across the time series. Actual basis is not known to the producer when the hedge is placed, therefore basis estimates were calculated using historic basis information. In addition to the actual basis, the 3-year average basis, 5-year average basis, and an Olympic average basis was calculated for each weight class. These served as expected basis values used in this analysis when estimating the forward price offered in the futures market for each hedging opportunity.

$$\text{Basis} = \text{Cash Price} - \text{Futures Price}$$

Equation 2: Basis Formula

Feeder cattle basis dynamics change with the weight of feeder cattle being purchased or sold in the cash market. Cash prices for feeder cattle decrease non-linearly as weight increases, while the feeder cattle futures contract is written for animals weighing between 700-800 lbs. This can lead to the difference in basis across weight classes of feeder cattle and is one challenge that must be overcome when hedging lighter weight feeder calves. Lighter weight cattle sell at higher price per hundredweight than heavier weight cattle which typically leads to a positive basis because futures contracts are priced for an 700-800 lb. steer. Similarly, heavier weight cattle tend to have a lower cash price than the underlying futures contract which leads to a negative basis.

Figure 4 shows the actual basis pattern for each sale weight class included in this analysis plotted from the first potential purchase week until the last potential sale week for all years included in the analysis. Basis tends to strengthen from the fall to the spring for lighter weight

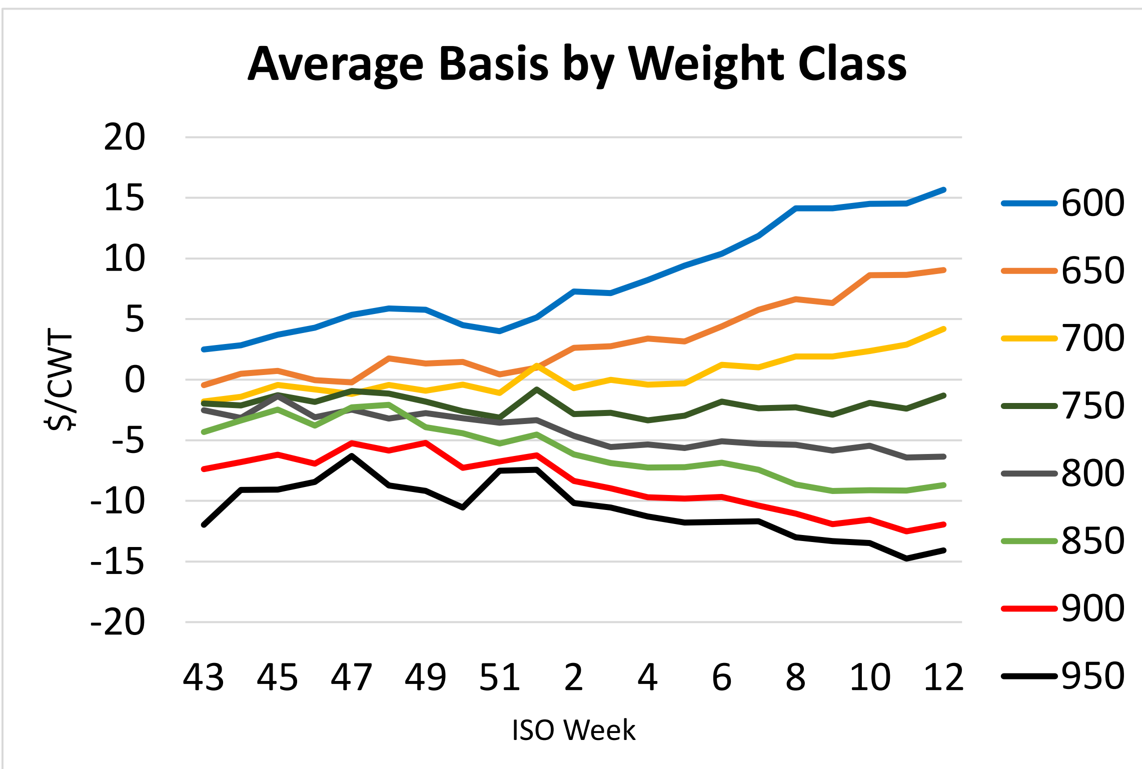

Figure 4: Average Basis Weight Line Chart

animals and weakens from fall to spring for heavier weight classes. From a fundamental supply perspective there are a greater proportion of light weight classes available in the fall and supplies of lighter weight calves are smaller in the spring leading to a typically stronger basis.

In addition to varying between weight classes, basis varies between years for each weight class, but tends to follow a consistent pattern for the production scenario analyzed in this study. The following charts characterize the differences in March basis that occurs in different years for different sale weight included in this analysis. Lighter weight classes have the most volatile basis levels between years for this period and tend to track a wider basis pattern relative to heavier weight classes that are closer in weight to the specification of the feeder cattle futures contract.

Different basis patterns and basis volatility have the potential to impact hedging success (Garcia & Sanders, 1995). A strong basis indicates that the cash price is higher than the futures price, while a weak basis indicates that the cash price is lower than the futures price. Changes in the basis level reflect how the cash and futures market prices change together over time. For basis to strengthen, cash price can increase while futures price stays the same, or cash prices may stay relatively the same while futures prices decrease. Figures 5 to 12 illustrate the seasonal basis pattern by year for each sale weight. As a contract nears expiration, like the March contract does in the figures below, cash and futures prices should converge to exhibit a narrow basis or a basis that is near $0.00 (Purcell & Koontz, 1999). Weight classes that are closer to the specification of the feeder cattle contract of 800 lbs. illustrate convergence more than lighter weight classes. Differences in basis convergence may lead to challenges in effectively hedging weight classes that are below 750 lbs. The tendency for basis to strengthen on lighter weight classes indicates that the cash market may be more likely to outperform the futures market for lighter weights. Examining when the most effective time of when to place a hedge and if timing of a hedge is difference between weight classes is discussed in the results section.

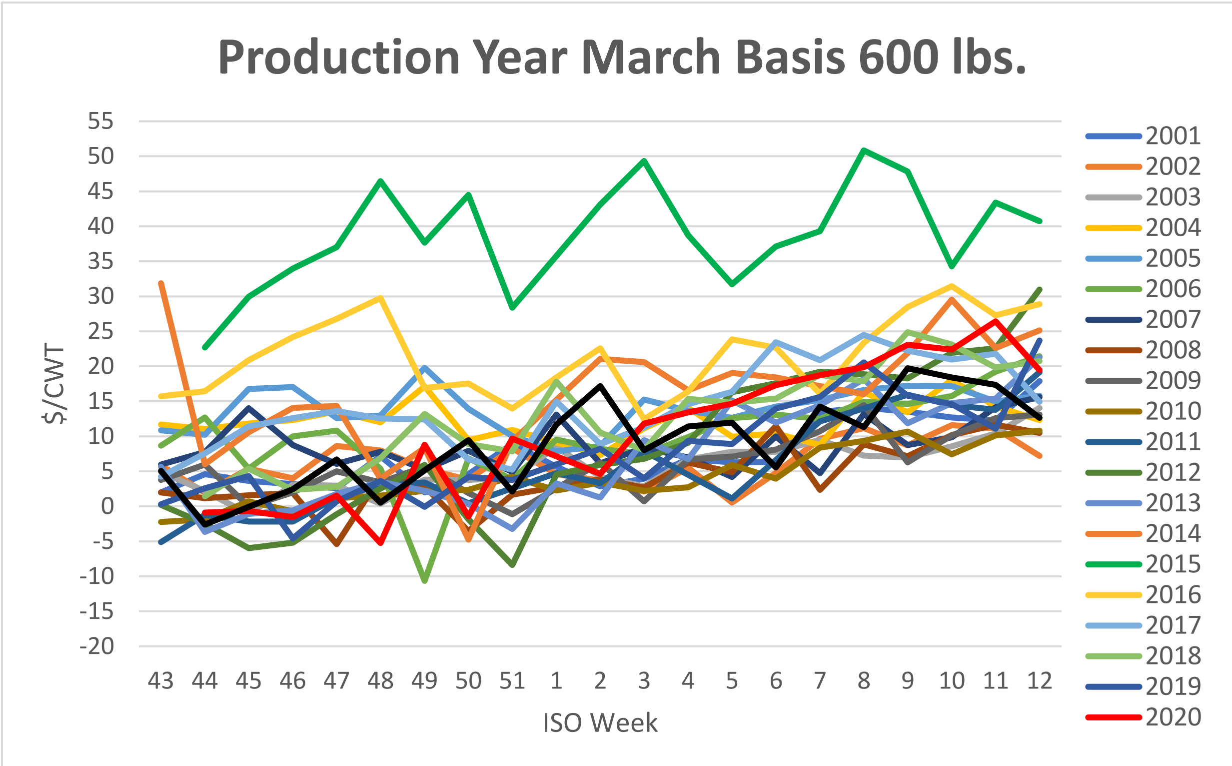

Figure 5: March Basis 600 lbs. Line Chart

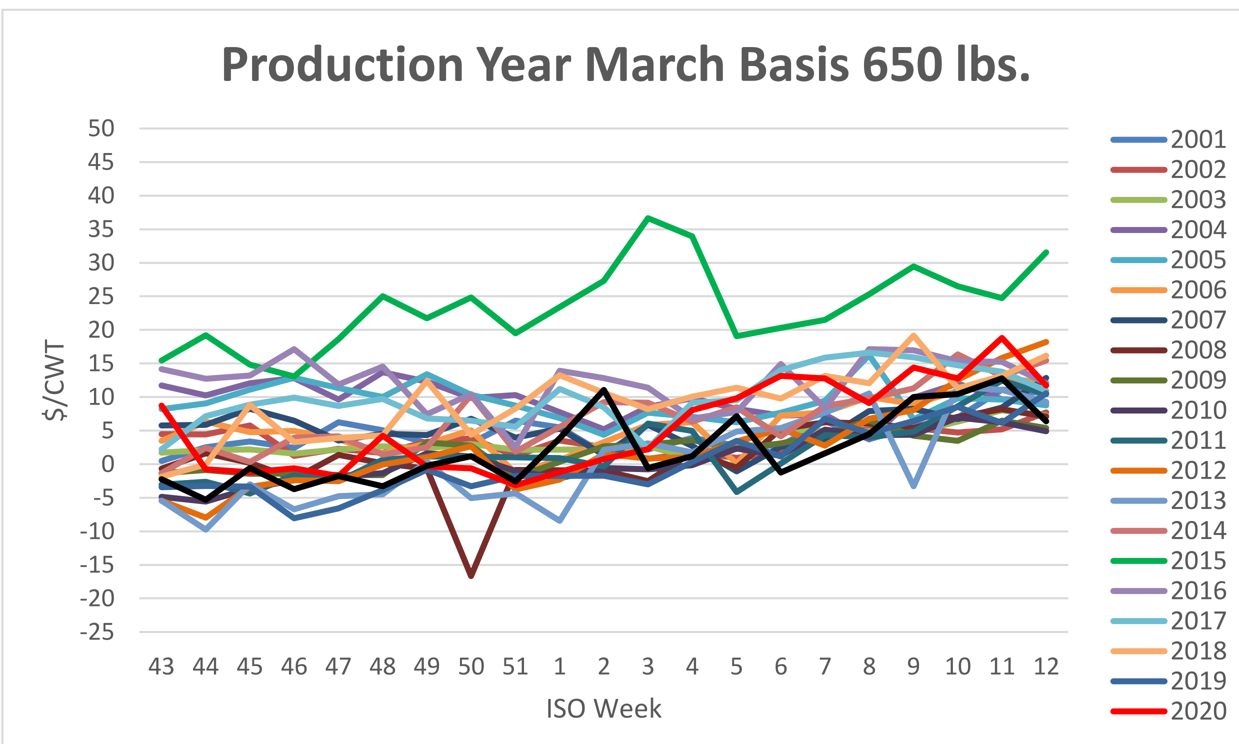

Figure 6: March Basis 650 lbs. Line Chart

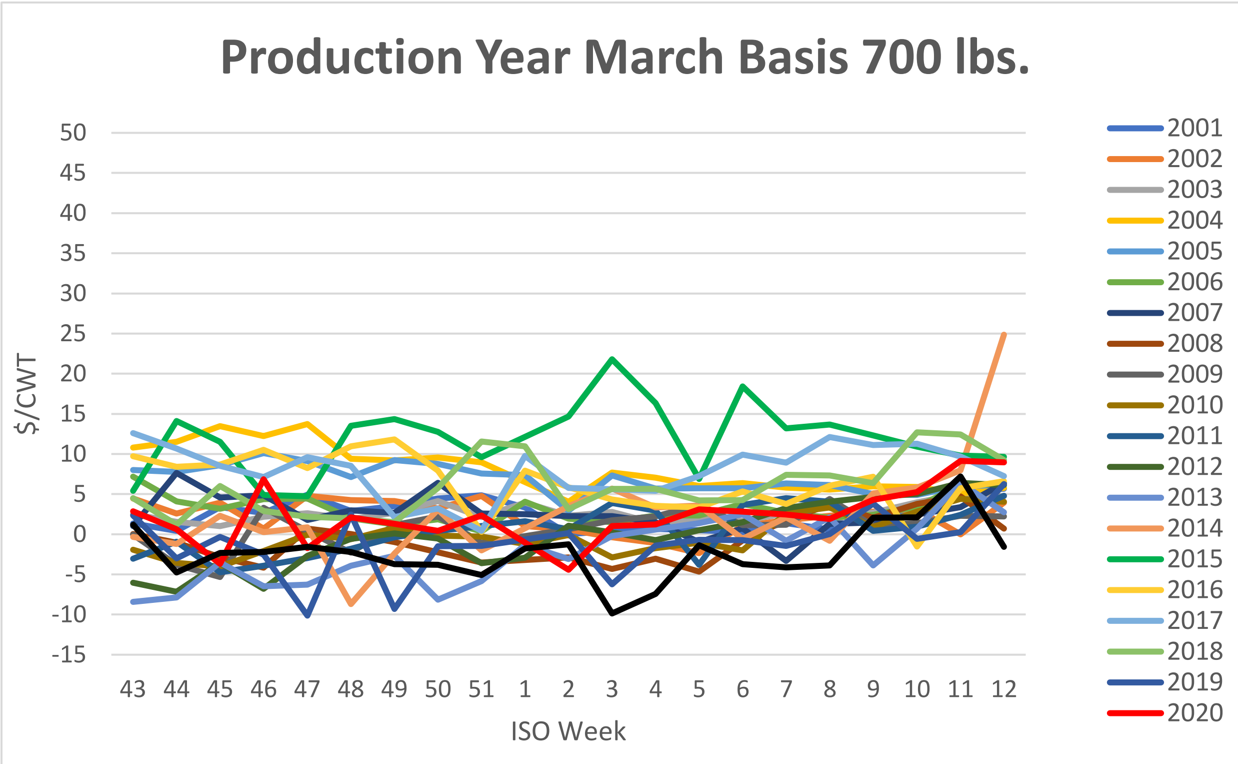

Figure 7: March Basis 700 lbs. Line Chart

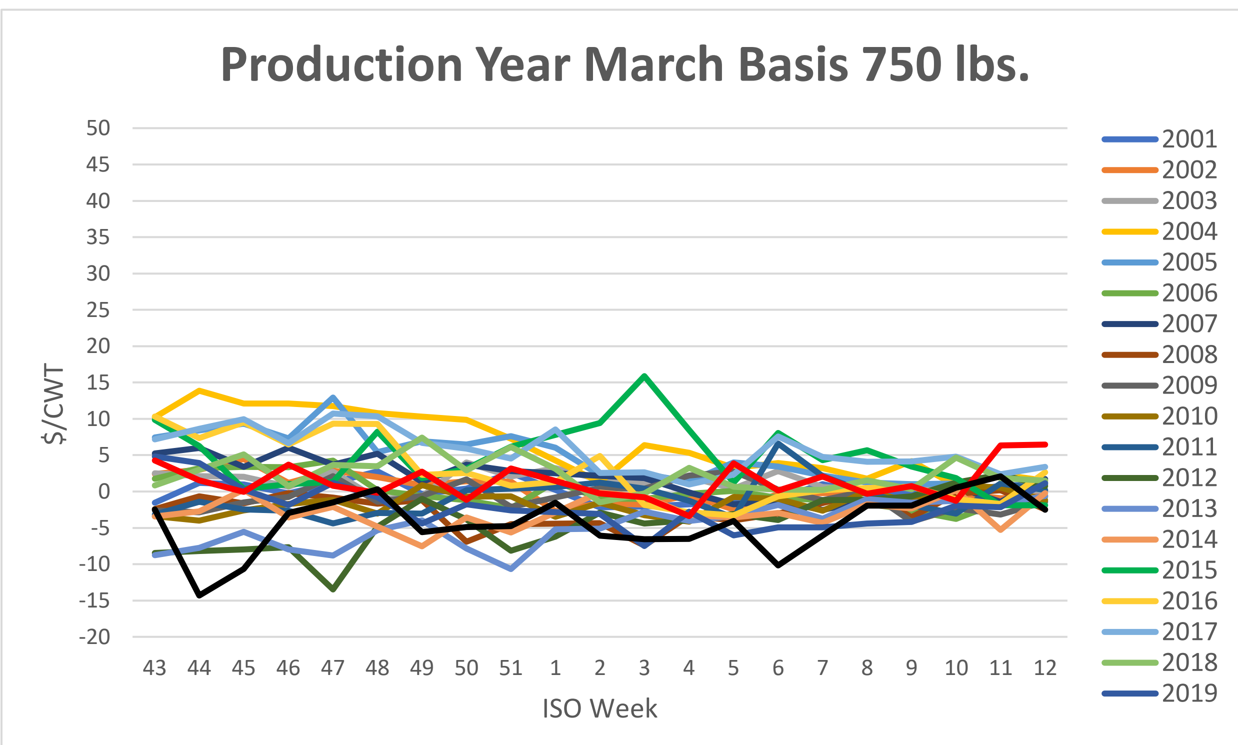

Figure 8: March Basis 750 lbs. Line Chart

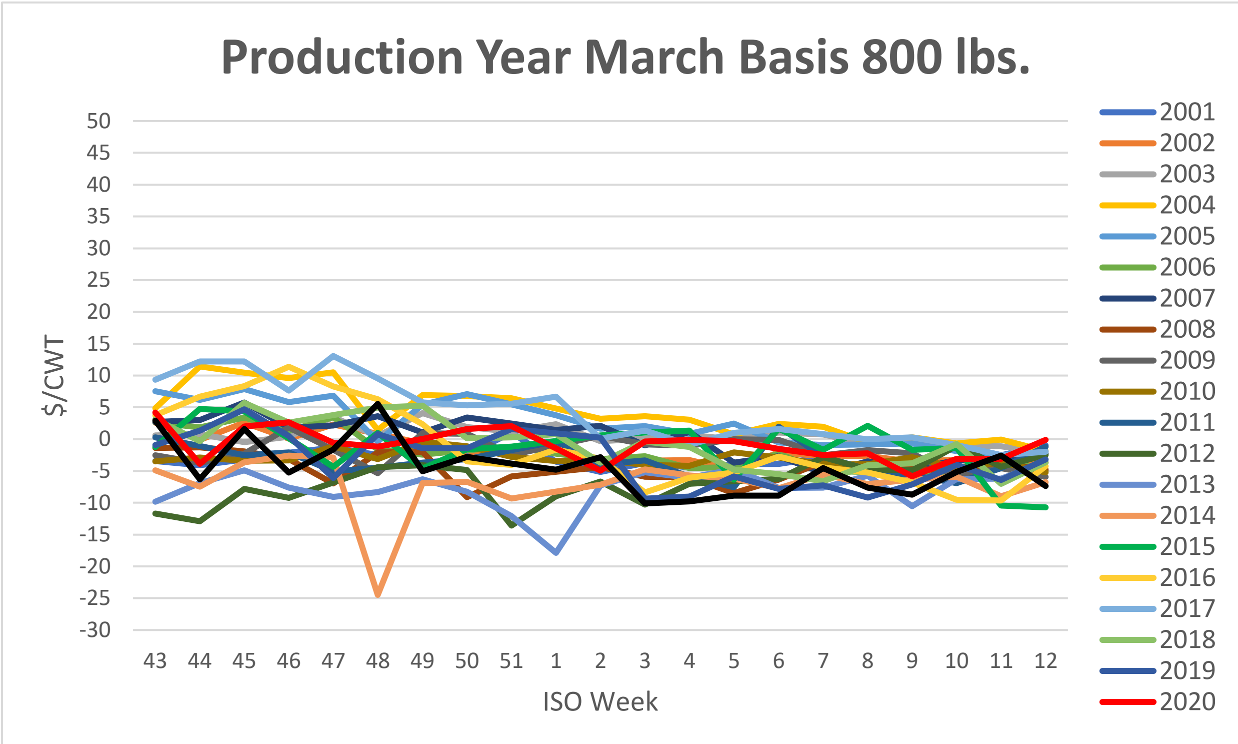

Figure 9: March Basis 800 lbs. Line Chart

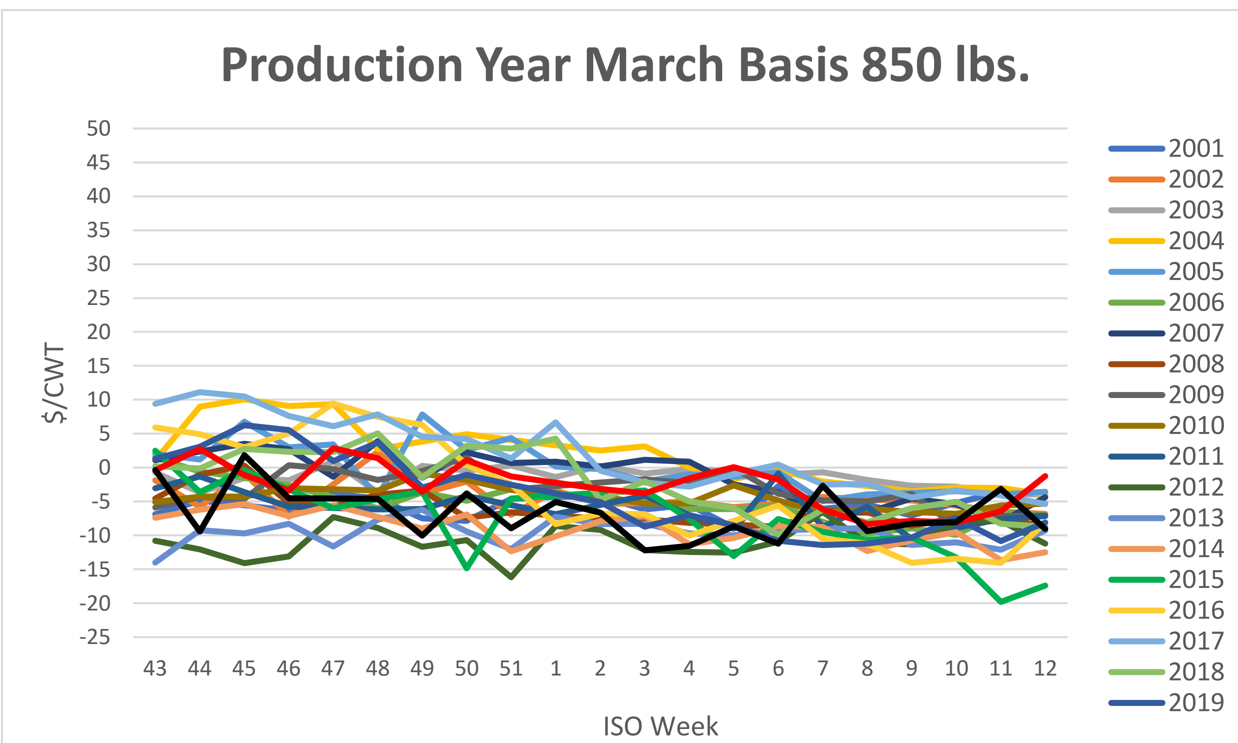

Figure 10: March Basis 850 lbs. Line Chart

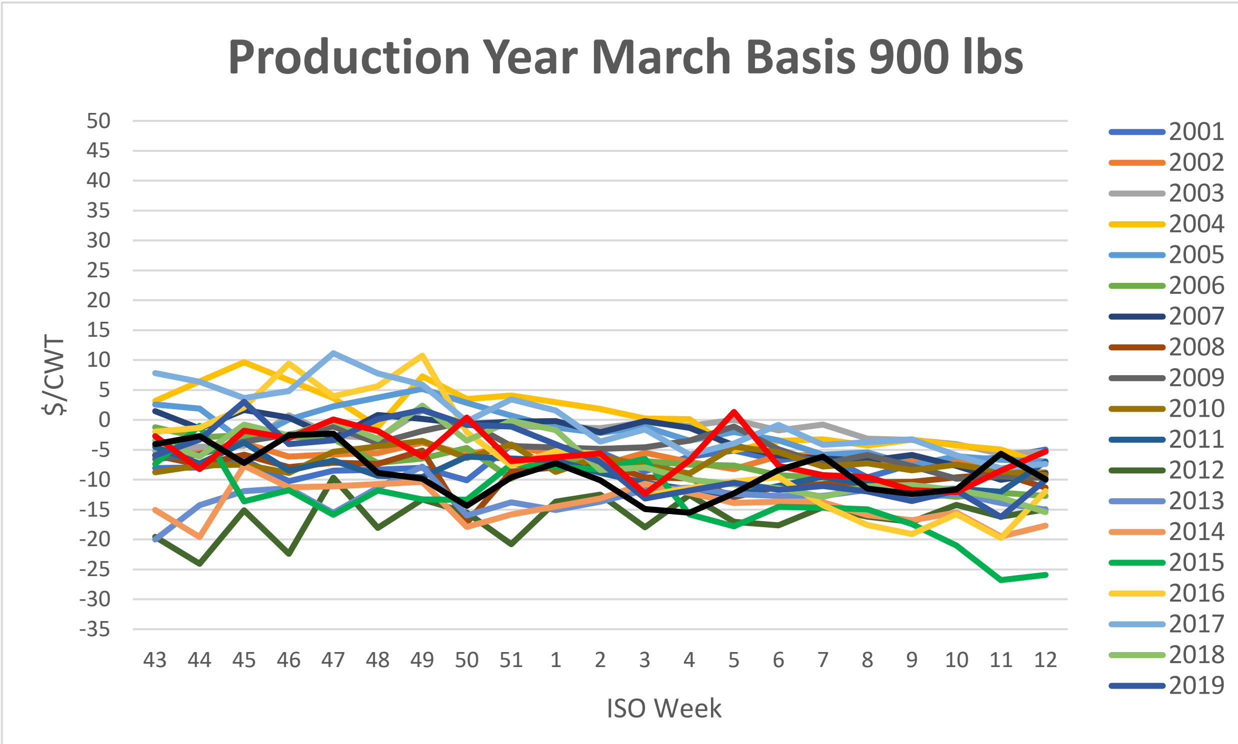

Figure 11: March Basis 900 lbs. Line Chart

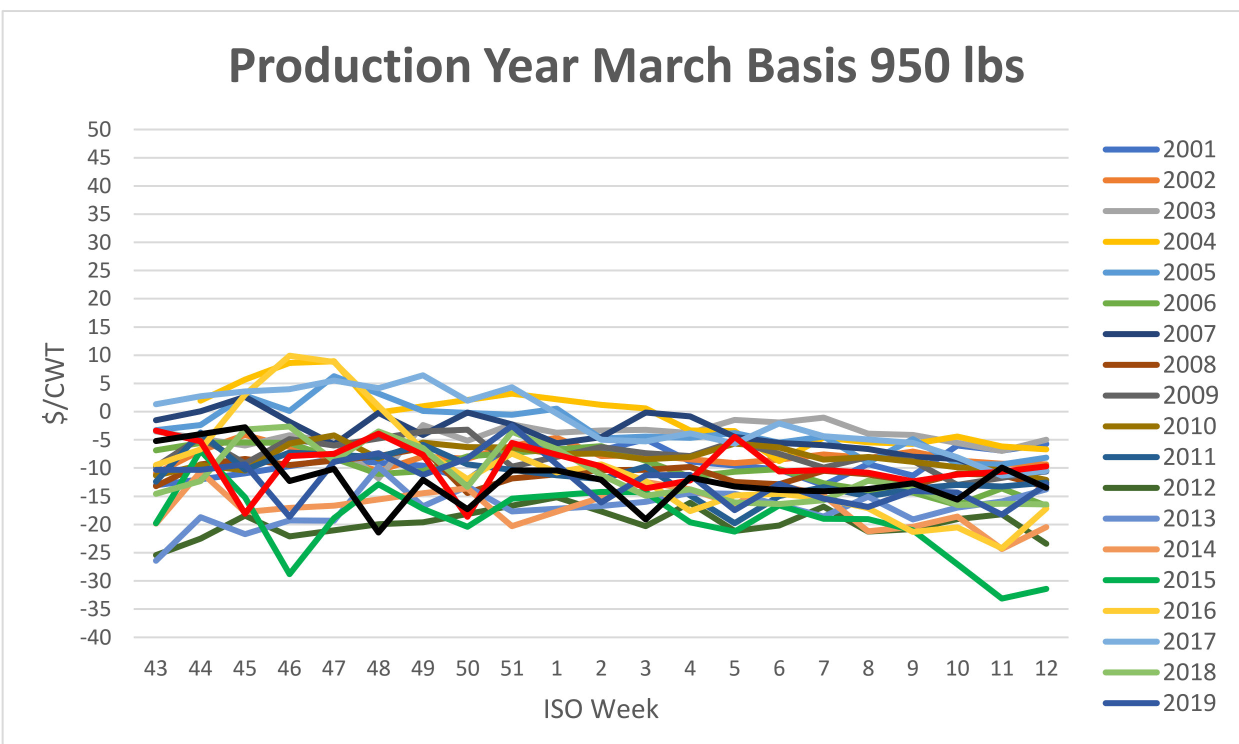

Figure 12: March Basis 950 lbs. Line Chart

4.3 Basis Model

In addition to historic basis evaluation, a basis model using linear regression was developed to improve estimated basis forecasts. Actual basis was estimated for each weight class using the regression equation below. The forecasted basis was then used to basis adjusted futures for the hedge scenario only to generate expected gross margins.

$$Actual\ Basis_{si} = \alpha + \beta_1 WT_{si} + \beta_2 WT_{si}^2 + \beta_3 PDSI_p + \beta_4 CornClose_p + \beta_5 OpenBasis_{pi} + \beta_6 PurchaseWeek_{44} + \beta_7 PurchaseWeek_{45} + \beta_8 PurchaseWeek_{46} + \beta_9 SaleWeek_{10} + \beta_{10} SaleWeek_{11} + \beta_{11} SaleWeek_{12}$$

Where WT_{si} is equal to the sale weight class, WT_{si}^2 is sale weight class squared, $PDSI_p$ is equal to the Oklahoma Palmer drought severity index in the purchase month, $CornClose_p$ is equal to the weekly average March corn futures close in the purchase week, and $OpenBasis_{pi}$ is equal to the actual basis for sale weight class i in the purchase week. Sale weight class and sale weight class squared are included to account for change in cash price per hundredweight (Bina, Schroeder, & Tonsor, 2022). Palmer drought severity index is included to account for changes in forage conditions between years and the availability of grazing to the stocker operator. March corn close is included to account for the effect of corn price at the time cattle are expected to be placed in a feedlot in this scenario and capture the impact of corn price on feeder cattle weight price slide (Dhuyvetter & Schroeder, 2000). The actual basis of the sale weight at the time of purchase is included to capture the starting basis level for each weight class. Basis was expected to typically follow a seasonal pattern as illustrated in the previous figures. The regression relies on the seasonal basis patterns that occur for each weight class.

4.4 Hedge Margin

Traditional hedge returns were evaluated for each scenario with every week from the week of purchase through the week of sale serving as a potential hedging opportunity. The hedging weeks for a given scenario varied based upon the purchase week and sale week for each observation and it is assumed that the hedge would always be lifted on the same week the cattle are sold in the cash market. Under the traditional hedge, it was assumed the producer would sell a March or April feeder cattle futures contract. The weekly average close price plus the basis, which corresponds to the sale weight, sale week, and sale year, serves as a hedged forward price for each observation. Forward price was calculated using the actual, 3-year average, 5-year average, and Olympic average basis. Each forward price was then used to calculate a projected gross margin for each scenario.

Under the hedge analysis, the purchase price and purchase weight are known and were used to calculate the average purchase cost. By adding the corresponding basis to the weekly average futures close price, the forward price was used to calculate the expected sale revenue by multiplying the forward price by the sale weight. The expected gross margin for each potential hedge week was calculated by subtracting the known purchase cost from the expected sale revenue.

Hedge Gross Margin: $(SW*(FP+CB_{SW}))/100 - (PW*PP)/100 = HGM$
Hedge Gross Margin: $(600*(140+10))/100 – (400*175)/100 = \$200/hd.$

Equation 3: Hedge Gross Margin Calculation

Where SW is the sale weight, FP is the average close price of the corresponding futures contract in the week the hedge is placed, CB is the closing basis of the sale weight class at the time the cash sale occurs for an observation, PW is the purchase weight, PP is the average price for the corresponding weight class PW during the purchase week, and HGM is the estimated hedge gross margin. Because the hedge was placed in the same week or after the purchase week, the purchase cost is always known in the hedge evaluation.

4.5 Spread Margin

A calendar spread trade is similar to the traditional hedge but includes an additional component in the futures market. When implementing a spread trade, the producer will also purchase a fall feeder cattle futures contract in addition to the sale of the selected spring feeder cattle contract. Under the spread scenario, both the purchase and sale of the stocker animal were hedged using the corresponding futures contracts. These positions were entered and exited simultaneously, although entering or exiting simultaneously is not a requirement in practice, it aided in the practicality of the analysis. In practice, the hedger could offset the November position and hold the short position through the expiration of the spring contract. An important stipulation to this method was that it must be executed prior to the expiration of the fall futures contract. The fall contract selected for all scenarios in this analysis was the November feeder cattle contract which expires on the last day of November. Based on the parameterized purchase weeks in this analysis, contract expiration was not an issue.

A producer could implement this spread trade from the time the March contract begins trading with sufficient liquidity and volume each year, until the time the November contract expires. Each week from the beginning of June to the end of November was the designated spread window in this analysis to ensure both the March and April feeder cattle contracts were trading with sufficient volume.

For the spread analysis, the spread trade was evaluated from ISO week 22 until the physical purchase of cattle in the cash market scenario. ISO week 22 was selected because it aligns with the first week of June in most years and ensures sufficient trade volume of the spring contracts has occurred. The limit on executing the spread trade was set by the purchase week and purchase year for an observation. The November contract price was basis adjusted by adding the basis that corresponds to the observation's purchase weight, purchase week, and purchase year to the weekly average November feeder cattle futures close price for each week in the spread interval. The basis adjusted price served as the forward purchase price. The forward purchase price was multiplied by the purchase weight to generate the forward purchase cost.

To calculate the forward sale cost, the March or April contract price was basis adjusted by adding the basis that correspond to the observation's sale weight, sale week, and sale year to the weekly average March or April feeder cattle futures close price for each week in the spread interval. The basis adjusted sale price serves as the forward sale price. The forward sale price was multiplied by the sale weight to generate the forward sale revenue. Finally, to calculate expected gross margin under the spread analysis, the forward cost was subtracted from the forward revenue.

Spread Gross Margin: $(SW*(FP+CB_{SW}))/100 - (PW*(FP_{Nov}+CB_{PW})/100 = SGM$
Spread Gross Margin: $(600*(140+10))/100 – (400*(160+15))/100 = \$200/hd.$

Equation 4: Spread Gross Margin Calculations

Where SW is the sale weight, FP is the average close price of the corresponding futures contract in the week the spread is placed, CB_{SW} is the closing basis of the sale weight class at the time the cash sale occurs for an observation, PW is the purchase weight, FP_{Nov} is the average price of the November futures during the purchase week, CB_{PW} is the closing basis of the purchase weight class at the time the cash purchase occurs for an observation, and SGM is the estimated spread gross margin.

CHAPTER 5: RESULTS

The previous sections have outlined the motivation, objective, and methods used to obtain the results that will be discussed in this chapter. This chapter begins with visual distributions of cash gross margin returns. Next, Section 5.2 describes hedge gross margin returns for both the March and April contract and conveys the differences between using the two contracts and the cash returns in section 5.1. Section 5.3 explains spread gross margin returns using November futures to hedge the purchase action, and March and April futures to hedge the sale action. Section 5.4 compares average gross margins by return type to convey differences in average margin and standard deviation between marketing methods. Section 5.5 discusses the results of the basis model and the differences between the expected margin for hedge returns using the model output compared to historic basis levels.

5.1 Cash Gross Margin Estimates

Figure 13 shows average cash gross margin returns averaged $198.14/head over the entire constructed cash matrix dataset. Standard deviation over the entire data series was $96.13/head. The table 5 shows disaggregated cash gross margin returns by sale year. Each sale year encompasses all observations for the possible combinations of purchase weeks, purchase weight, gain, sale weeks, and sale weight. The highest cash return occurred in 2012 while the lowest return occurred in 2015. The results indicated cash returns are larger and more variable after 2010. The average return from 2001 to 2010 was $148.75/head while the average return from 2011 to 2021 was $243.03/head. The standard deviation ranged from 24.89 to 34.43 from 2001 to 2010 while standard deviation ranged from 35.06 to 73.03 from 2011 to 2021. Increases in the standard deviation in returns indicate that returns have become more volatile over time adding to the risk the producer faces in the cash market.

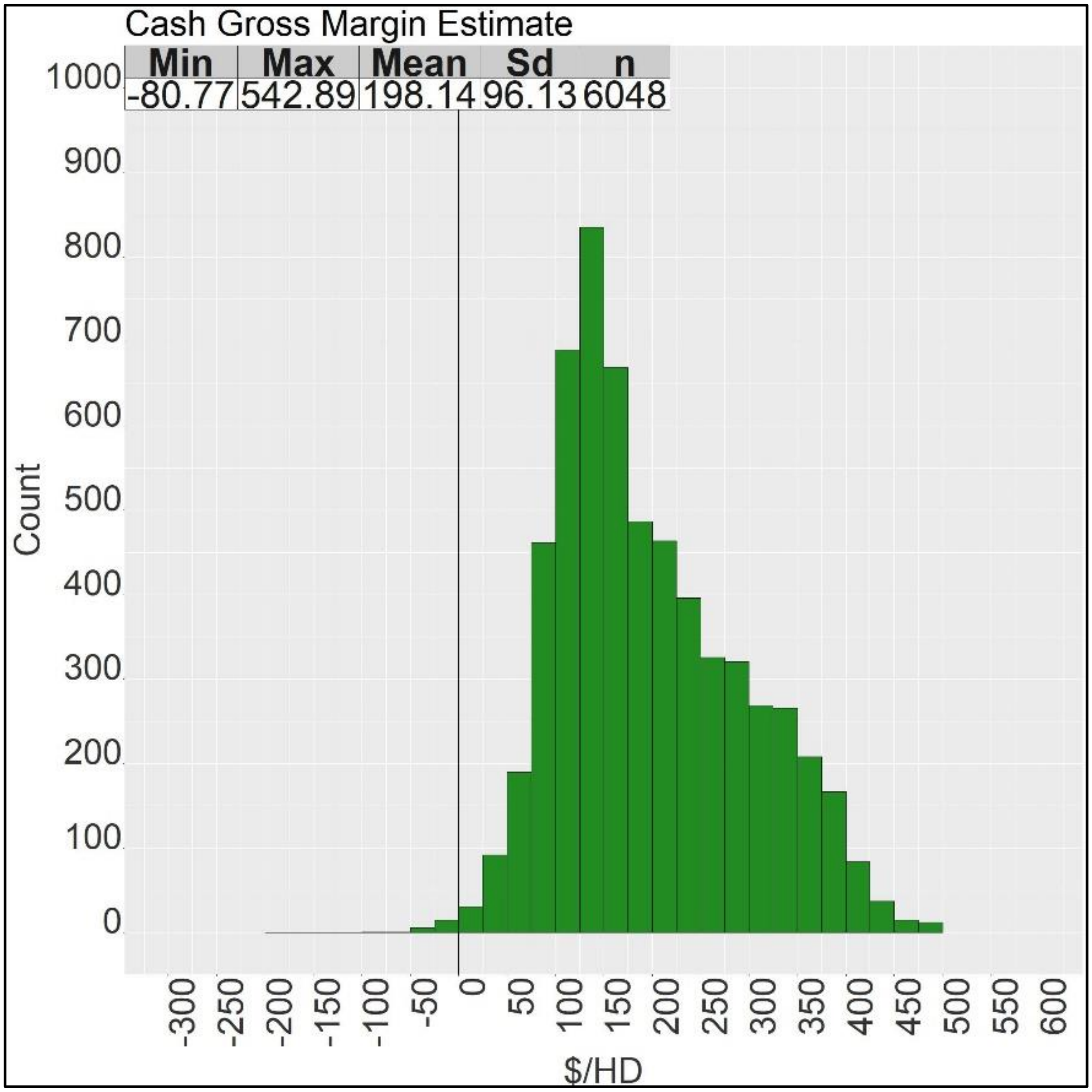

Figure 13: Cash Gross Margin Estimate

Table 5 shows average cash returns over the 21-year period. Figure 14 includes the distribution of returns for all observations subset by sale year. It is important to note the price levels from 2011 to 2021 were higher relative to 2001 to 2010, but this increase in price level applies to both sale weights and purchase weights. Returns after 2011 tended to be larger but more volatile in comparison to the prior decade. Returns prior to 2011 illustrated a more uniform distribution between years as well as lower mean gross margins. Furthermore, standard deviation for returns prior to 2011 were lower than returns after 2011. The average standard deviation prior to 2011

Table 5: Cash Margins by Sale Year

Year	N	Mean	Std. Dev.	Min	Max
2001	288	152.42	24.89	89.42	226.00
2002	288	127.34	28.81	39.76	194.61
2003	288	121.95	26.95	65.21	194.67
2004	288	116.25	28.77	28.00	190.11
2005	288	157.06	32.59	74.09	253.99
2006	288	105.66	29.93	36.39	175.88
2007	288	195.83	33.55	112.18	278.02
2008	288	148.99	34.43	65.44	239.15
2009	288	115.45	26.96	37.64	194.28
2010	288	246.58	31.53	166.12	320.29
2011	288	354.05	35.01	268.32	448.14
2012	288	382.81	47.85	252.60	507.97
2013	288	203.06	41.40	86.46	332.22
2014	288	327.57	47.84	219.11	542.89
2015	288	99.04	64.11	-80.77	275.81
2016	288	107.71	64.41	-46.55	322.79
2017	288	289.20	50.42	173.68	410.94
2018	288	219.27	61.90	20.73	368.83
2019	288	224.69	51.41	112.02	375.12
2020	288	182.68	73.03	-2.37	334.69
2021	288	283.25	59.06	155.84	451.53
Total	**6048**	**198.14**	**96.13**	**-80.77**	**542.89**

was $29.84/head, while the average standard deviation from 2011 forward is $54.22/head.

The record setting drought from 2010 to 2012 resulted in mass liquidation in the beef cowherd

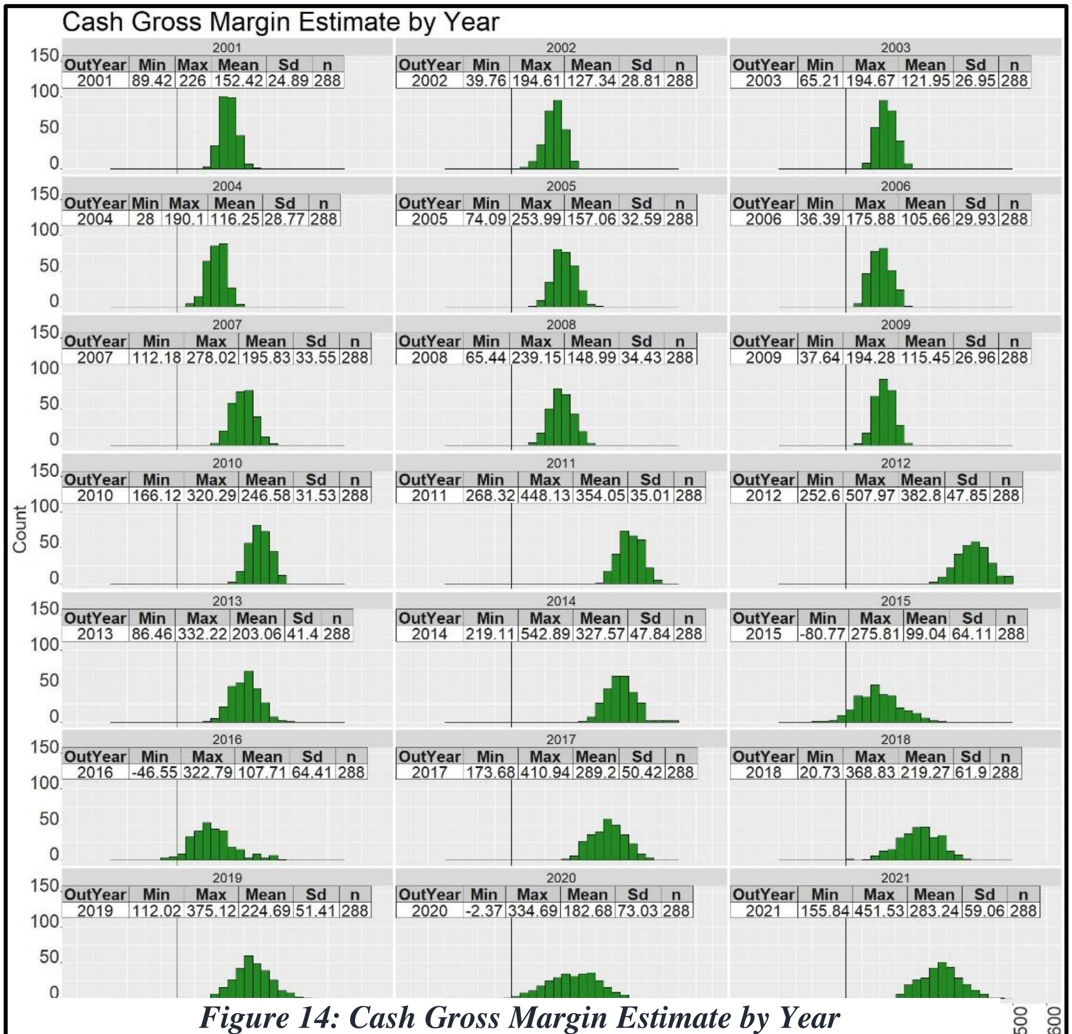

Figure 14: Cash Gross Margin Estimate by Year

resulting in significantly lower feeder cattle supplies (Leister, Paarlberg, & Lee, 2015). A shortage of calves placed upward pressure on prices across multiple sectors of the cattle industry. Record prices were established in fed cattle and feeder cattle alike, and these increases prices were reflected in the margins from 2012 to 2014 (Hurt, 2014). As expected, when prices moved lower off record highs, cash gross margin was negatively impacted by the abrupt price move. The lowest average cash gross margin in this analysis occurred in 2015, and the third lowest cash gross margin occurred in 2016. Additionally, the highest standard deviation occurs in the 2015 sale year. Results of the cash analysis agree with findings that greater volatility in prices has increased volatility of returns in the stocker cattle sector. Furthermore, margins were shown to vary significantly between years contingent upon a production year's price environment. There are elevated levels of risk to gross margin returns in a falling price level environment.

Disaggregated cash returns by amount of gain, illustrated in figure 15, showed that over the entire dataset that higher gain resulted in higher average returns. Average returns for 300 lbs. of gain were $28.95/head higher than average returns for 250 lbs. of gain and $56.44/head higher than average returns for 200 lbs. of gain. Average returns for 250 lbs. of gain were $27.49/head higher than average returns for 200 lbs. of gain. The highest max return was in the 300 lbs. of gain category, while the lowest minimum return was in the 200 lbs. of gain category.

Amounts of gain were also disaggregated by each of the 21 sale years. Each year contains 96 observations and the relationship between amounts of gain was consistent with the largest amount gain leading to the highest returns when each amount of gain is compared between the same years. This was not unexpected as each amount of gain will include observations of the same purchase weights but different sale weights in this analysis. Data including observations with 300 lbs. of gain contain sale weight observations that skew towards heavier weights which gave the larger amount of gain the revenue advantage between all years when compared to smaller amounts of gain. The results confirmed the importance of gain and its impact on gross margin.

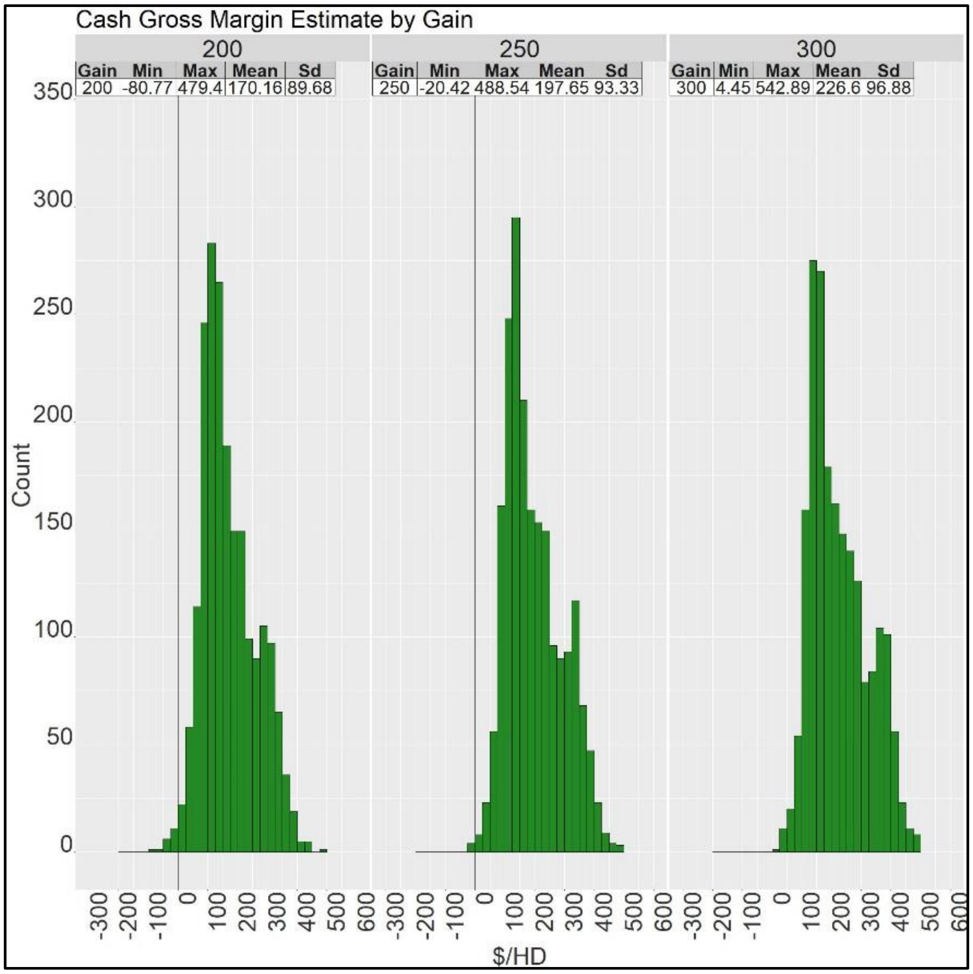

Figure 15: Cash Gross Margins Estimate by Gain

Figure 16 shows the distributions of cash gross margins subset by purchase weight were similar but illustrated an interesting dynamic of stocker cattle production. Across all years, the lightest purchase weight class yielded the highest average gross margin. Gross margin decreased slightly for the 450 lb. purchase weight class, while the difference in gross margin between the 500, 550, and 600 lb. purchase weight class was quite minute. The heaviest purchase weight class resulted in the lowest average gross margin return relative to the other purchase weight classes. Purchasing a 400 lb. steer had a $17.23/head advantage to purchasing a 450-pound steer with minimal difference in standard deviation. Buying a 400 lb. steer had a $26.20/head, $28.25/head, $25.72/head, $41.24/head larger mean return compared to purchasing a 500 lb., 550

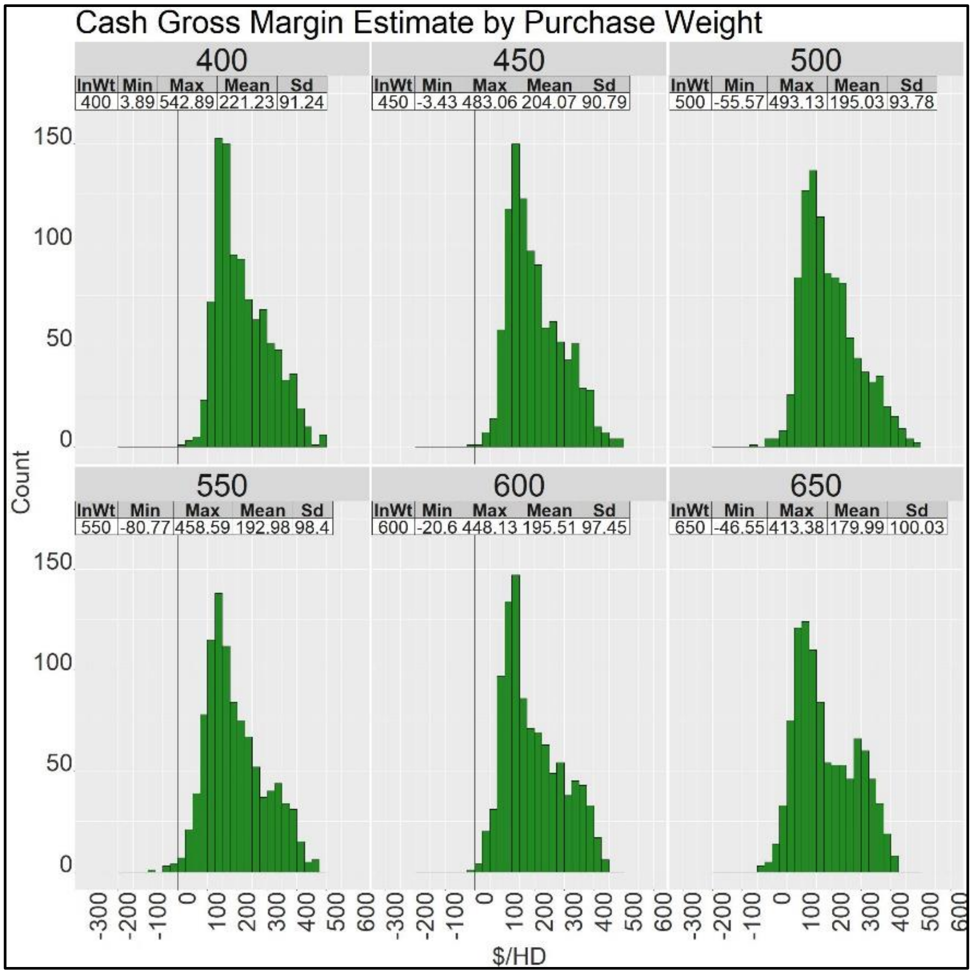

Figure 16: Cash Gross Margin Estimates by Purchase Weight

lb., 600 lb., and 650 lb. steer, respectively. This demonstrated that there may be an advantage in buying lighter weight classes, as cattle can be purchased at a lower cost relative to the heavier purchase weights. It is important to consider that in practice lighter weight cattle may at times be higher risk and exhibit decreased performance due to higher rates of sickness and death loss than heavier weight classes. Higher rates of morbidity and mortality have a detrimental effect on performance and profit (Pinchak, et al., 2004). Therefore, the advantage in purchasing lighter weight cattle may not always hold.

Disaggregated total returns by sale weight, illustrated in Figure 17, showed that the highest average return was generated when selling a 950 lb. steer with the average return being

$211.61/head. Selling a 700 lb. steer generated the next highest average return at $206.21/head. Marketing an 850 lb. steer had the lowest mean return at $189.66/head. Although differences in

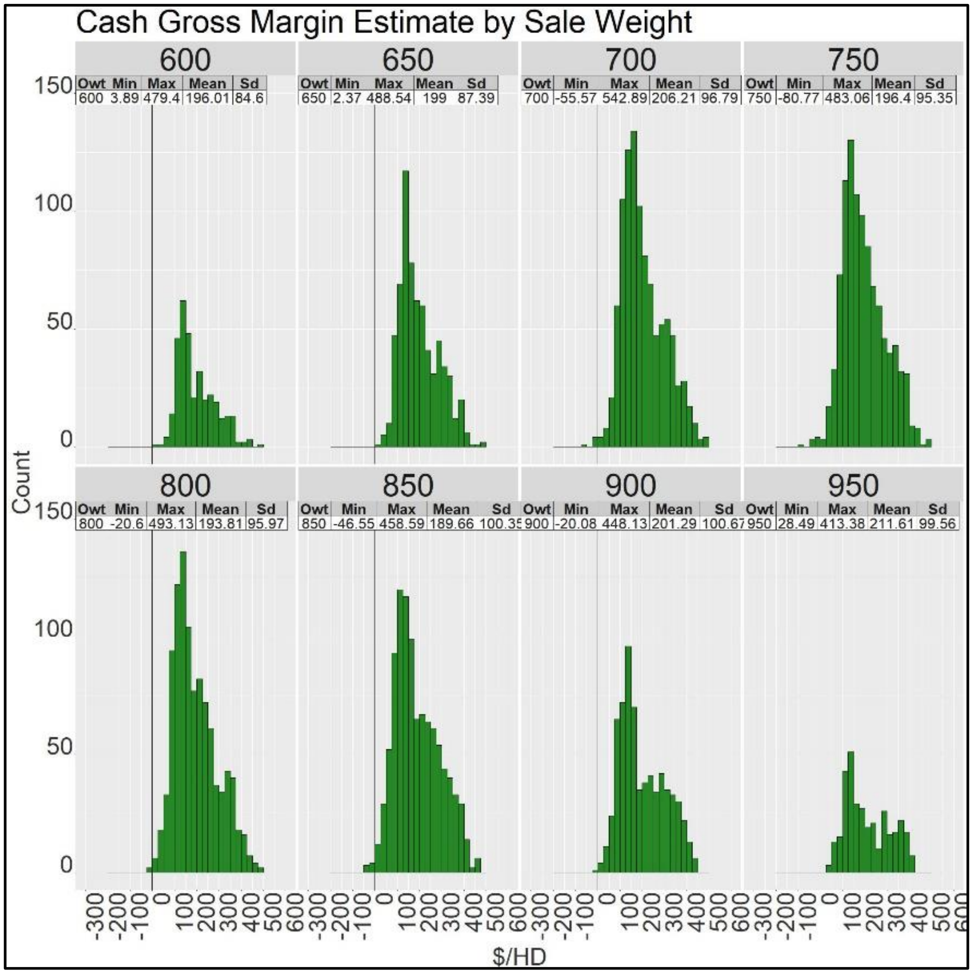

Figure 17: Cash Gross Margin Estimates by Sale Weight

cash margins occurred between sale weights, it was difficult to decern patterns and concrete advantages or disadvantages between marketing steers at different sale weights.

Sale weight is a function of starting weight and the amount of gain over the production period. Gain may vary significantly between groups of cattle and production years depending on animal performance, and the quality and availability of forage. In the stocker sector, the producer may have limited influence on the sale weight of cattle outside of implanting or providing nutritional supplementation.

5.2 Hedge Gross Margin Returns

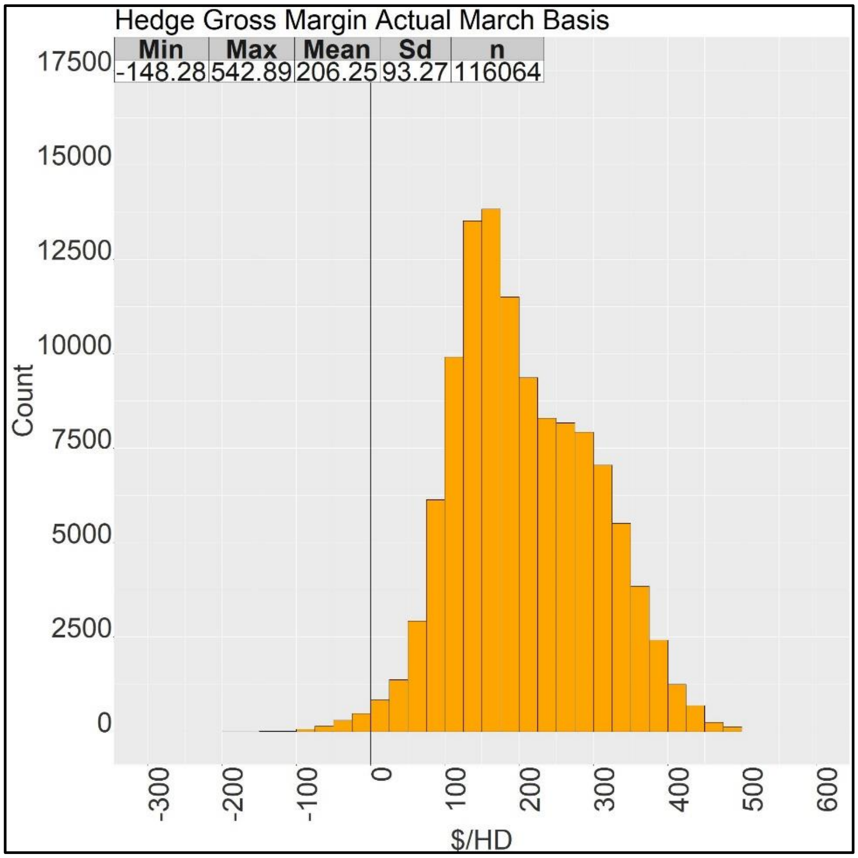

Figure 18: Hedge Gross Margin Actual March Basis

Figure 18 shows hedge gross margin returns applying actual closing March basis to forward price cattle based upon the sale weight averaged $206.25/head across the entire dataset, which was slightly higher than the cash average; the standard deviation was also slightly lower. There were significantly more observations in the hedge data because each scenario included every return from hedging using the forward sale price to calculate a return. The number of hedging opportunities and therefore hedge returns was dependent upon the purchase week and sale week in each observation. This had a multiplicative effect on observation number relative to the cash matrix. Figure 19 shows average hedge margins over the entire dataset using the April contract.

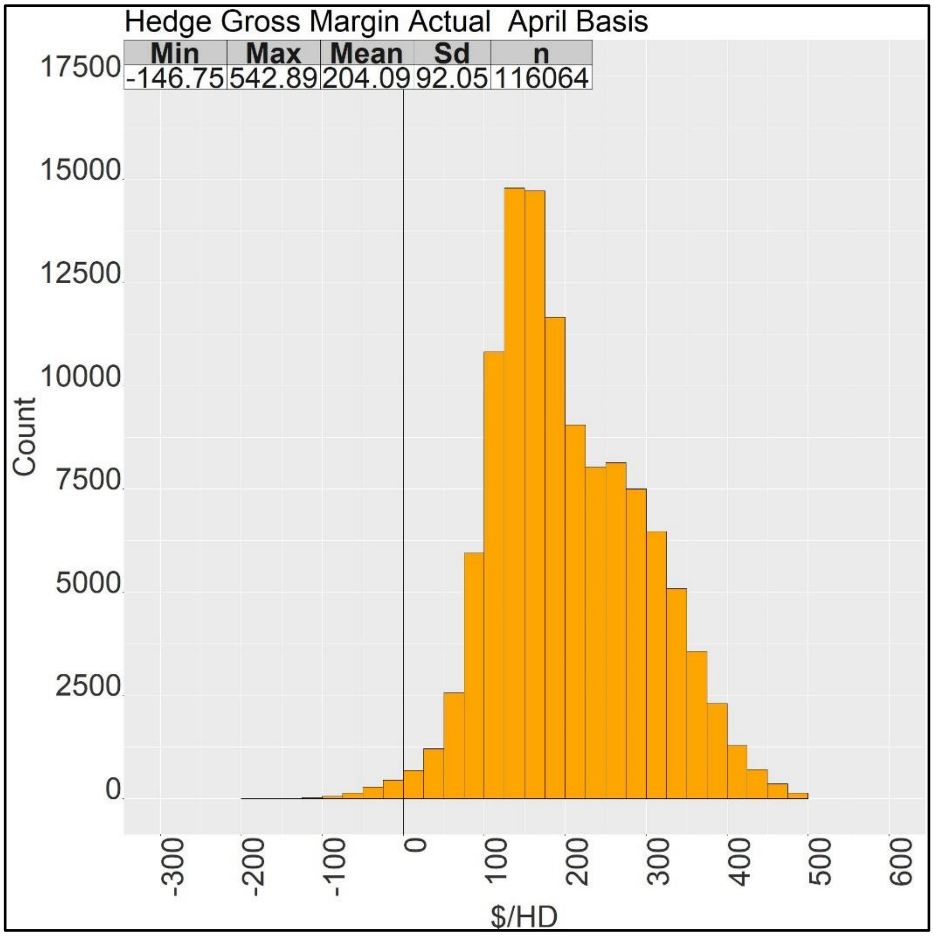

Figure 19: Hedge Gross Margin Actual April Basis

Hedge gross margin returns for the entire dataset using the April contract and actual closing basis yielded comparable results to that of the March contract. Mean returns and standard deviation using the April contract were slightly lower than the March returns at $204.09/head $92.05/head respectively but higher than cash returns. When comparing every hedge return opportunity using the actual closing basis to every cash return, the forward hedge yielded a higher return 56.05% of the time when using the March contract and 53.08% of the time when using the April contract**.** Disaggregated HGM returns using actual March basis by sale year illustrated differences relative to yearly cash returns. Table 6 and Table 7 show summary statistics for the hedge return using the March and April contract, respectively average actual hedge gross margin returns were greater than average cash gross margin returns in 12 of the 21 years when the March contract was used. April hedge returns were greater than cash returns in 10 of the 21 years.

Table 6: Hedge Returns March Contract

Hedge Return March Contract						
Year	**N**	**Mean**	**SD**	**Min**	**Max**	**Dif**
2001	5472	168.44	28.75	75.65	254.16	16.02
2002	5472	141.52	29.65	39.76	220.53	14.18
2003	5472	151.92	33.35	60.32	248.38	29.97
2004	5472	108.33	40.69	-29.25	224.95	-7.92
2005	5760	123.28	33.05	42.67	253.99	-33.78
2006	5472	154.67	37.00	36.39	250.57	49.01
2007	5472	146.72	39.69	25.68	288.10	-49.10
2008	5472	181.37	39.75	53.84	298.86	32.39
2009	5472	123.00	35.14	5.65	244.10	7.55
2010	5760	198.43	37.21	98.01	320.29	-48.15
2011	5472	304.59	52.25	151.49	456.38	-49.46
2012	5472	357.59	57.46	182.87	526.16	-25.22
2013	5472	276.24	57.03	86.46	451.33	73.18
2014	5472	287.45	51.08	154.86	542.89	-40.13
2015	5472	159.55	115.83	-121.82	496.23	60.51
2016	5760	100.85	83.21	-148.28	458.27	-6.85
2017	5472	261.96	52.43	116.93	424.05	-27.25
2018	5472	258.62	63.60	20.73	458.08	39.35
2019	5472	238.78	51.77	111.75	401.91	14.09
2020	5472	298.68	68.55	-2.37	454.51	116.00
2021	5760	294.85	62.03	122.73	504.01	11.61
Total	**116064**	**206.25**	**93.27**	**-148.28**	**542.89**	**8.11**

However, there were numerous hedging opportunities each year and the distribution of average returns for a production year does not demonstrate changes within the production year. Mean returns using the March contract prior to 2011 ranged from $108.33/head to $198.43/head with the lowest average return occurring in 2004 and the highest average return occurred in 2010.

Table 7: Hedge Return April Contract

Hedge Return April Contract						
Year	**N**	**Mean**	**SD**	**Min**	**Max**	**Dif**
2001	5472	162.04	27.49	73.10	247.41	9.62
2002	5472	141.82	29.48	39.76	218.65	14.48
2003	5472	150.32	31.92	61.39	245.44	28.37
2004	5472	115.99	34.05	-17.02	209.53	-0.26
2005	5760	124.98	33.74	41.51	253.99	-32.08
2006	5472	145.14	34.30	36.39	233.18	39.48
2007	5472	144.47	40.80	26.17	287.70	-51.36
2008	5472	181.79	36.96	65.44	287.70	32.80
2009	5472	125.58	34.64	2.54	243.14	10.13
2010	5760	189.94	38.82	94.62	320.29	-56.64
2011	5472	297.63	54.54	143.37	460.24	-56.42
2012	5472	357.10	61.19	167.61	542.62	-25.71
2013	5472	272.25	55.19	86.11	441.41	69.19
2014	5472	281.33	51.79	145.78	542.89	-46.25
2015	5472	169.41	118.00	-128.64	514.71	70.36
2016	5760	103.98	84.43	-146.75	461.95	-3.72
2017	5472	260.47	54.01	103.44	425.25	-28.73
2018	5472	256.58	62.88	20.73	453.49	37.31
2019	5472	**217.74**	49.36	92.36	375.12	-6.96
2020	5472	**314.43**	72.55	-2.37	490.34	131.75
2021	5760	**279.06**	59.94	121.33	463.86	-4.19
Total	**116064**	**204.09**	**92.05**	**-146.75**	**542.89**	5.95

Mean returns after 2010 ranged from $100.85/head to $357.59/head and the lowest return occurred in 2016 and the highest return occurred in 2012. Prior to 2011, standard deviation ranged from $28.75/head to $40.89/head and averaged $35.43/head. After 2010, standard deviation ranged from $51.08/head to $115.83/head and averaged $65.02/head. Average March hedge returns from 2001-2010 were $149.77/head and average March hedge returns from 2011-2021 were $258.10/head. Average April hedge returns from 2001-2010 were $148.21/head with standard deviation of $34.22/head and average April hedge returns from 2011-2021 were $255.45/head with standard deviation of $65.81/head. Both contracts demonstrated the increase in return level and the volatility of returns over the last two decades when hedging output using the feeder futures market. Figure 20 shows the distribution of hedge returns for the March

Figure 20: HGM Actual March Basis by Sale Year

contract by sale year. The difference between mean returns for the March and April contracts was less than $10/head for all sale years except for 2019, 2020, and 2021.

A point of interest was the 2015 sale year where the cash and futures markets declined off record high price levels. Average hedge returns in the 2015 sale year had a higher standard deviation, higher mean return, higher maximum return, and lower minimum return relative to cash returns in the same sale year. Hedging during this year offered returns that would have allowed a hedger to secure a much higher margin as the market moved lower when the hedge was placed at the correct time and a much lower margin compared to cash if the hedge was placed after the market had declined in price level. Timing is clearly a key element in hedging but determining the optimal time to place a hedge can prove difficult.

Average hedge gross margin returns by basis type for the March contract are compared in Figure 21. In each of the 21 sale years showed minute differences between the actual hedge gross

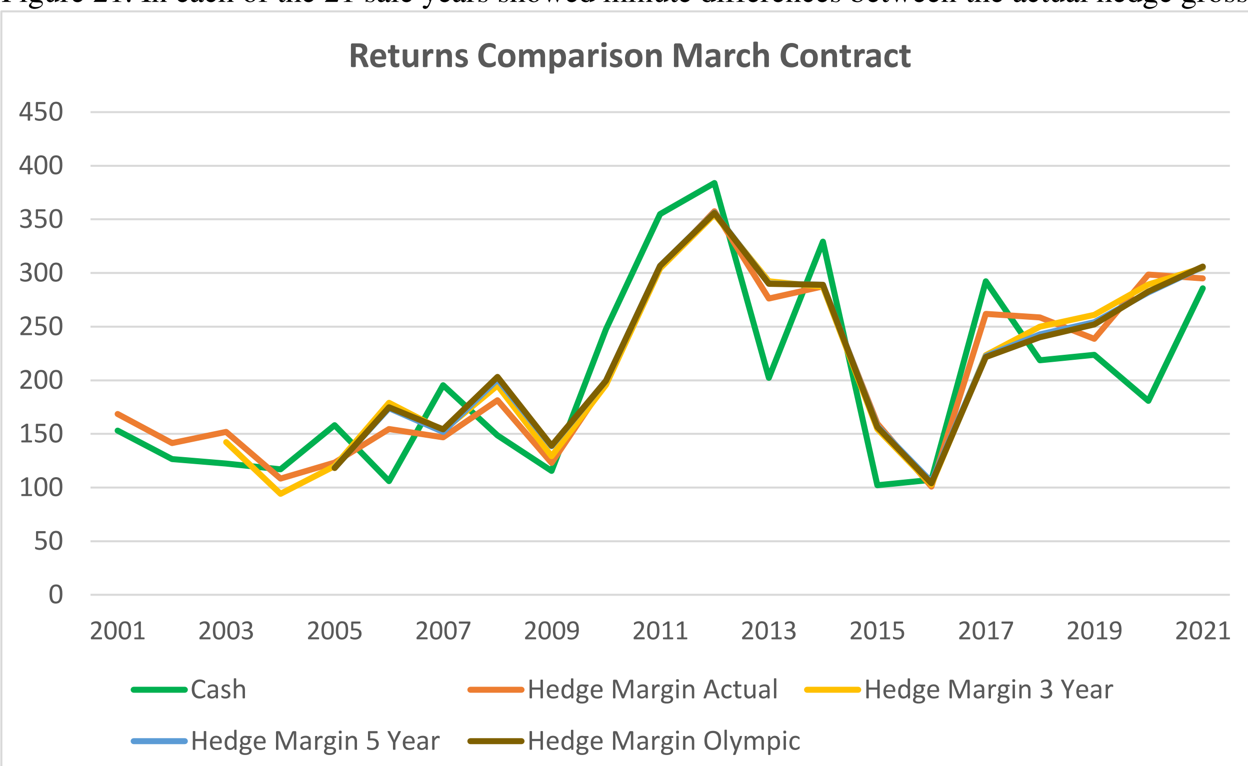

Figure 21: Returns Comparison March Contract

margin and the estimated forward margins derived from different lengths of historical basis. Margin estimates across all sale weight classes and observations in each sale year using different basis levels were relatively consistent. However, breaking down gross margins by sale weight, basis type, and production year showed variability in the effectiveness of different historic basis estimates.

Figure 22 illustrates seasonal hedging patterns subset by different production years from ISO week 43 to ISO week 12. The longest production interval was chosen to depict the hedge return pattern in each production year in its entirety. Changing the production interval would impact the actual and historic basis estimates and both cash and forward margins. All seasonal

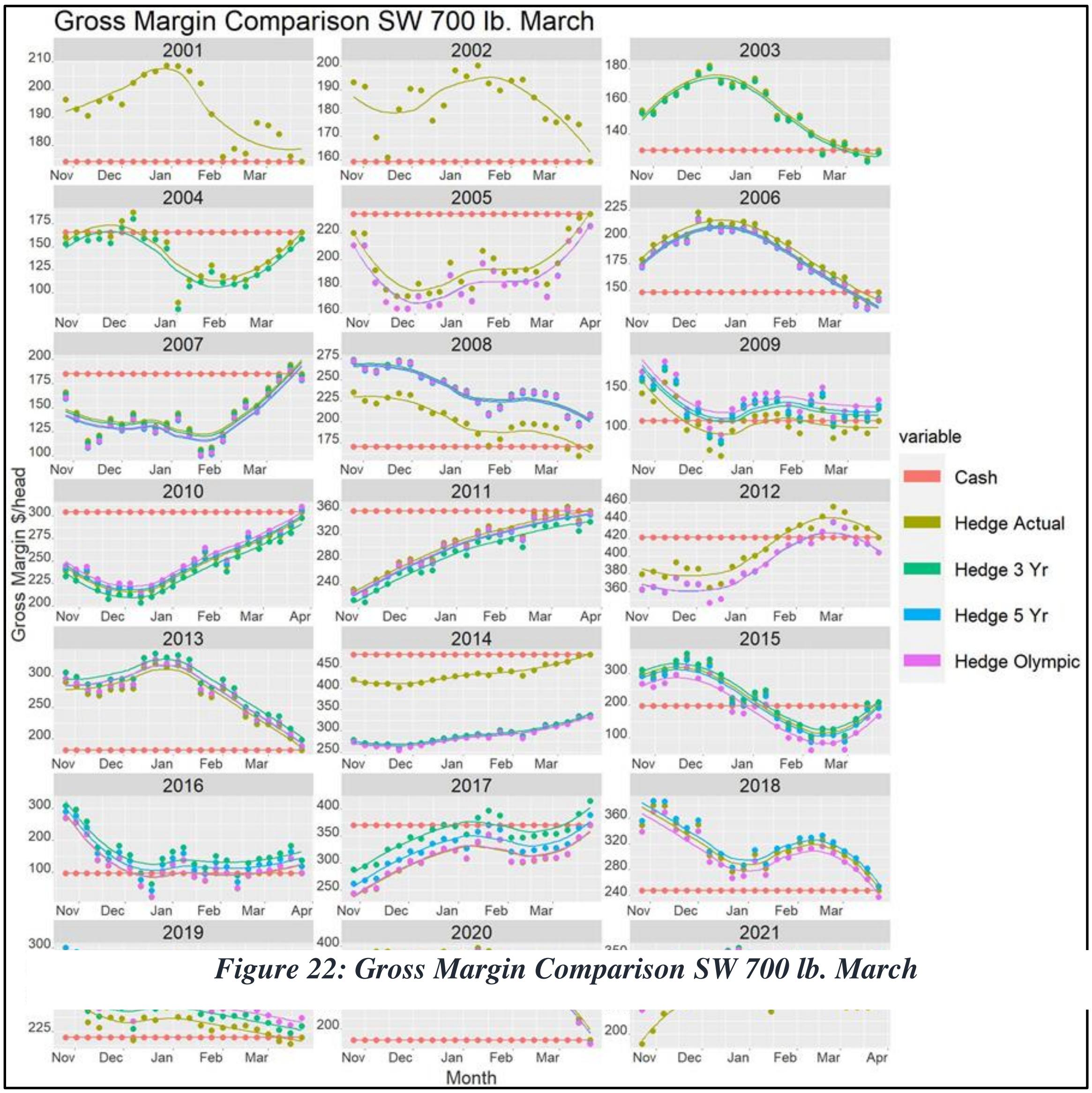

Figure 22: Gross Margin Comparison SW 700 lb. March

margin figures define the sale weight, contract month, and margin types plotted. For simplicity, only observations with 250 lbs. of gain were included in season margin figures.

The dotted red lines on the seasonal margin figures represent the average cash gross margin return for each sale year. The y-axis was adjusted to each sale year. Cash lines between years may appear to be at the same level of returns visually but represent different cash return levels such as the case between 2010 and 2011. Adjusting the y-axis for each sale year allowed the relationship between the estimated forward returns and cash returns to be expressed more effectively.

Hedge opportunities began in the fall of the year prior to the sale year and end in the spring at the time cash cattle were sold. Figure 22 illustrates how forward margins change within the production year and aided in understanding the timing of effective hedging. Hedge returns using actual basis that remain below the dotted red line throughout each year indicate futures never priced in a forward margin that would be better than the average cash margin received at the end of the grazing period in a production year. Conversely, actual hedge returns above the red line indicate a hedge could have been placed that would have secured a higher forward margin relative to the cash margin. March futures were adjusted using the actual closing basis or historic basis for the corresponding sale weight in ISO week 12. The actual basis represents the most accurate forward margin and would be the best-case hedging scenario for given year. Historic basis information was included to show the effectiveness of using historic basis to predict actual basis varies. Difference between actual margin and estimated margin is reflective of basis error.

Adjusting March futures using historic basis is shown to be reasonably effective in forecasting actual hedge margins in 11 out of 19 years for this sale weight and sale week including 2003, 2004, 2006, 2007, 2010, 2011, 2013, 2015, 2016, 2018, and 2020. Analyzing the actual and historic basis margins using a different sale week or different sale weight may not show the same effectiveness due to difference in the basis value and cash returns between sale weeks. The 2001 and 2002 production years do not have historic basis information because the price series in this analysis only dated back to 2000. 2003 and 2004 only included the actual basis adjusted forward margin and 3-year average basis adjusted forward margin. Historic basis estimates occasionally underestimated actual basis, such as in 2005, 2012, 2014, or overestimated basis such as in 2008, 2019, 2021.

The historic basis tracks the actual basis trend, but this was primarily because each basis type is constant for every observation in each sale year. The change in forward margins throughout the production year was solely dependent upon price movement in the futures market. If a producer was going to hedge the week or soon after cattle were purchased, then 2001, 2002, 2003, 2008, 2009, 2013, 2015, 2016, 2018, 2019, and 2020 would have allowed the producer to achieve a higher margin than the average cash gross margin return within the first few weeks of ownership. However, in 2010, 2011, 2012, 2014, 2017, and 2021 the opposite is true, and hedging right away leads to lower returns than the average cash gross margin. Adjusting April futures using historic basis showed similar margin patterns as the March contract and similar variability in the effectiveness of using historic basis to predict forward margins. Figure 23 shows historic basis is reasonably effective at predicting actual forward margin in 2003, 2006, 2007, 2010, 2011, 2015, 2016, 2018, and 2020 for a 700 lb. steer or 9 out of 19 years.

Differences in returns between the contracts used were dependent upon the weekly spread in close prices and the difference in basis between contracts.

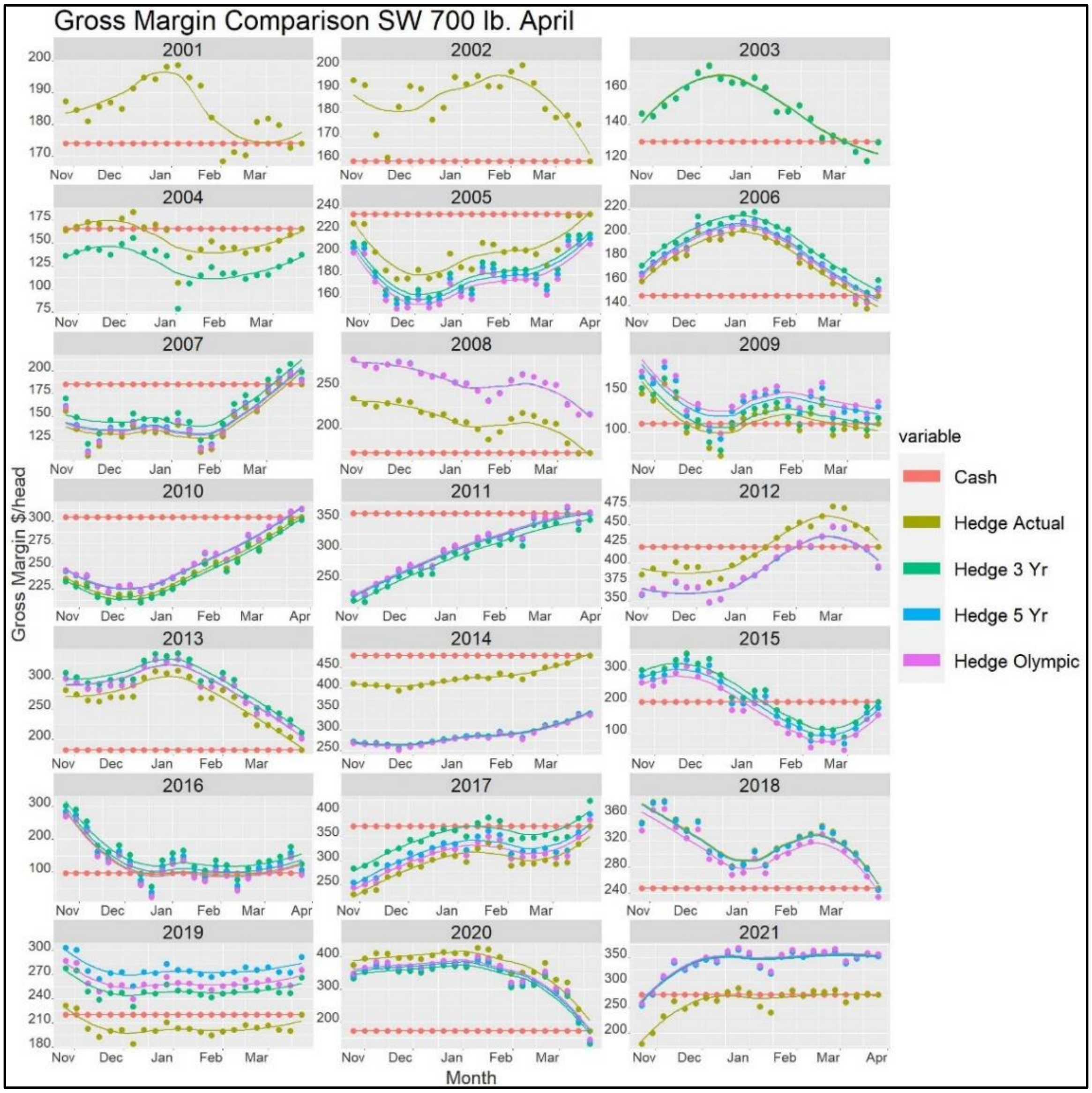

Figure 23: Gross Margin Comparison SW 700 lb. April

Furthermore, the effectiveness of historic basis varied between weight classes. Figure 24 showed that using historic basis showed a greater tendency to overestimate or underestimate March contract forward margins for the 650 lbs. sale weight class in comparison to the 700 lb. sale weight class. Other weight classes that were either lighter or heavier than the weights specified in the feeder cattle futures contract also reflected that historic basis was less accurate at predicting the actual basis. This aligned with expectations of greater basis variability in weight

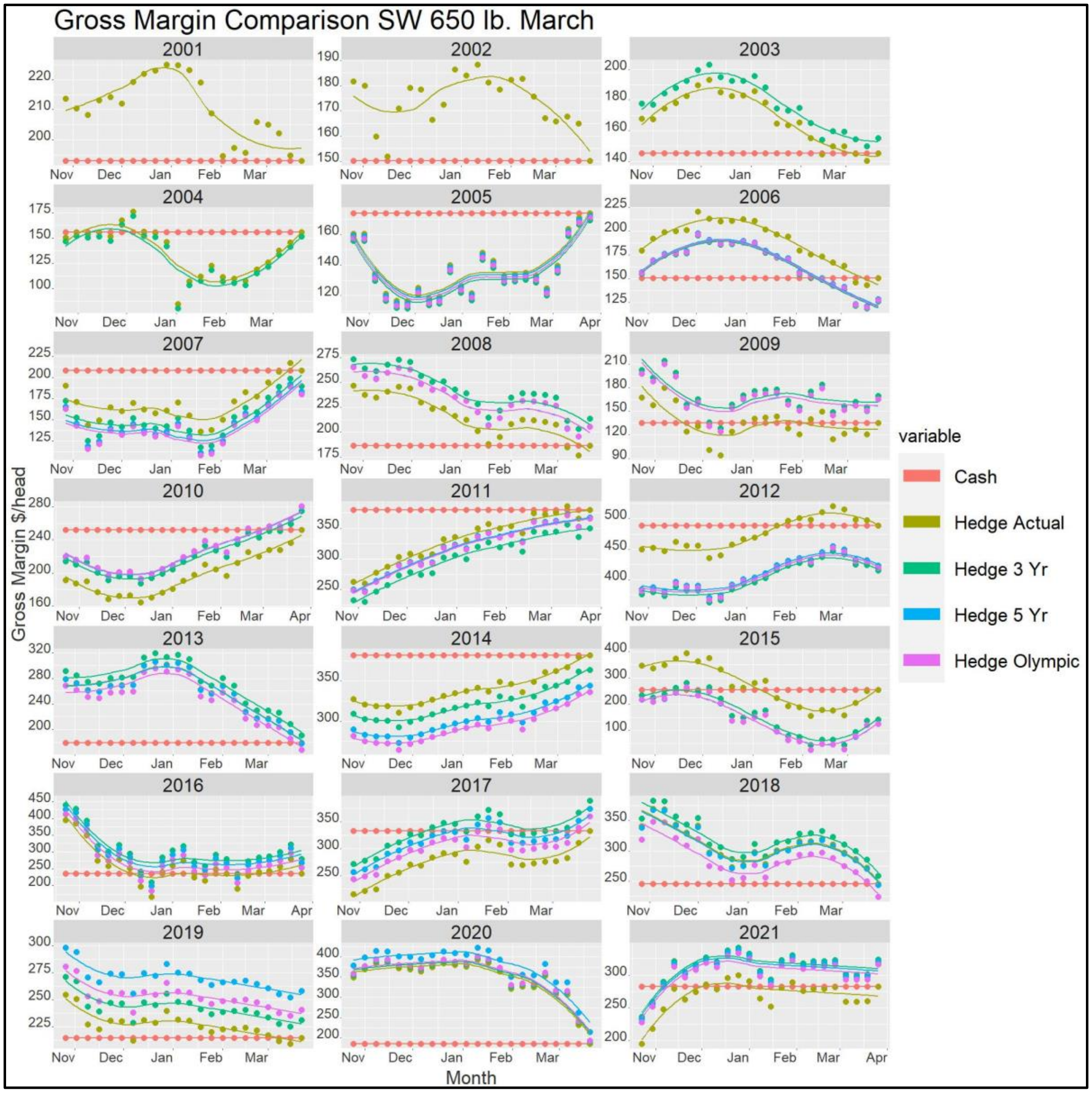

Figure 24: Gross Margin Comparison SW 650 lb. March

classes that are more distant from the 800 lb. weight class specified in feeder cattle futures contracts.

The optimal time to place a hedge varied significantly depending on the market environment. The seasonal forward margin patterns in 2012 and 2015 demonstrated that the optimal time to place a hedge occurred in opposite times between sale years. In 2012, the lowest forward margin was offered in the fall, and highest forward margin was offered in the spring; in 2015, the highest forward margin was offered in the fall, and the lowest forward margin was offered in the spring. Additionally, production years 2010 and 2013 also exhibited opposite optimal hedge patterns. This specific relationship was consistent across weight classes regardless of gross margin level.

Although margin patterns varied between production years, margin patterns appear consistent between sale weight classes in the same production year. Even though cash gross margin and forward gross margins differ between weight classes the seasonal hedge patterns all exhibited the same pattern across years. The main implication being that the optimal time and least optimal time to place a hedge in a given production year was uniform across weight classes.

Examining Figures 22, 23, and 24 illustrated how hedge margins change throughout the production year. In years where forward gross margin seasonally increases, the cash market tends to offer a higher return. Outside of 2004 and 2005, when hedge gross margin begins to decrease within the production year the forward margin offers a return that is higher than the cash return. Additionally, when hedge margin increases then begins to decrease within the production year it may function as a signal that the market is offering a hedgable return that is higher than the cash market return received at the end of the period. This signal occurs in 2001, 2002, 2003, 2006, 2013, 2015, however 2004 may be classified as a false signal. Further research is necessary to confirm the reliability of these patterns for hedging purposes.

5.3 Spread Gross Margin Returns

Figure 25 shows that over the entire span of the data set, March spread gross margin returns had a higher mean return, and lower standard deviation than either cash or hedge returns.

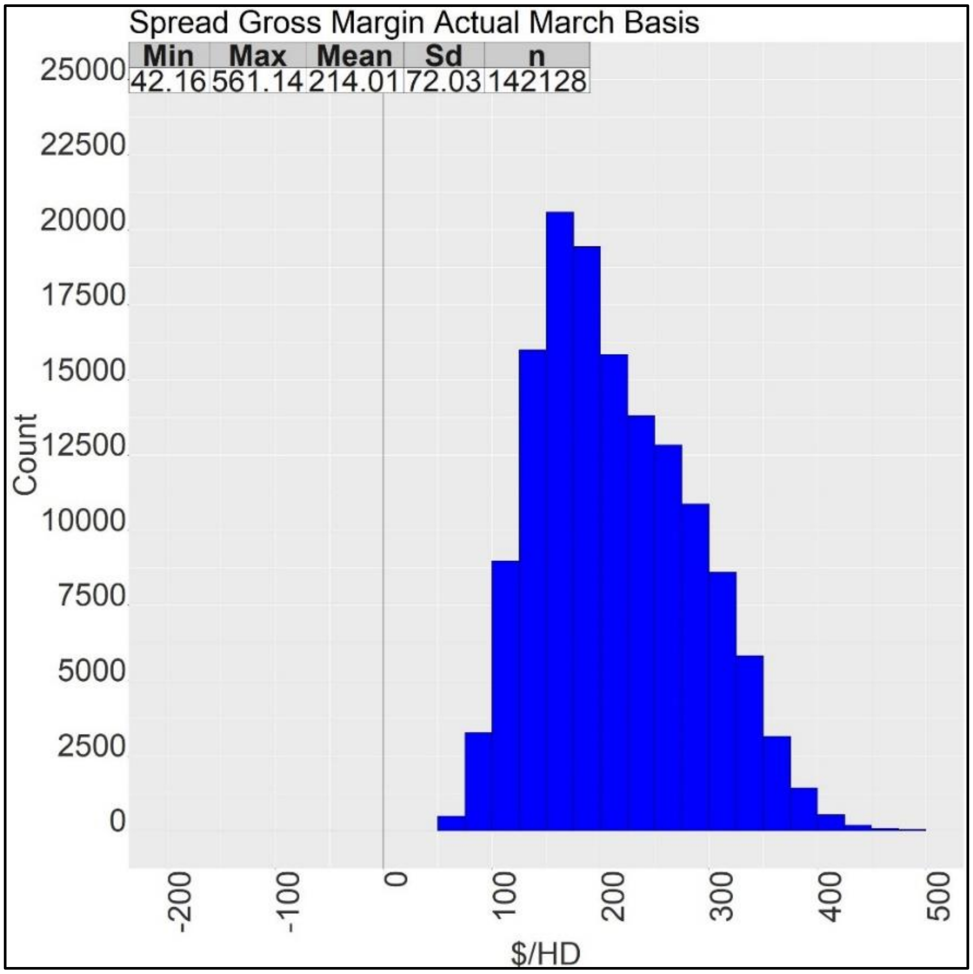

Figure 25: Spread Gross Margin Actual March Basis

March spread returns averaged $214.01/head and had a standard deviation of $72.03/head. The spread return included observations where both the purchase weight and sale weight were simultaneously hedged by basis adjusting the November feeder cattle futures contract using the actual basis, and basis adjusting the March or April feeder cattle futures contract using the actual basis to generate a forward purchase and forward sale price. Figure 26 shows that April spread gross margin returns averaged $206.90/head slightly lower compared to the March spread returns but a near equal standard deviation. Figure 26 illustrates the distribution of March spread returns using the actual closing basis by sale year. Table 8 shows March spread margins disaggregated by sale year. Spread return distributions were similar to cash and hedge returns. Mean returns

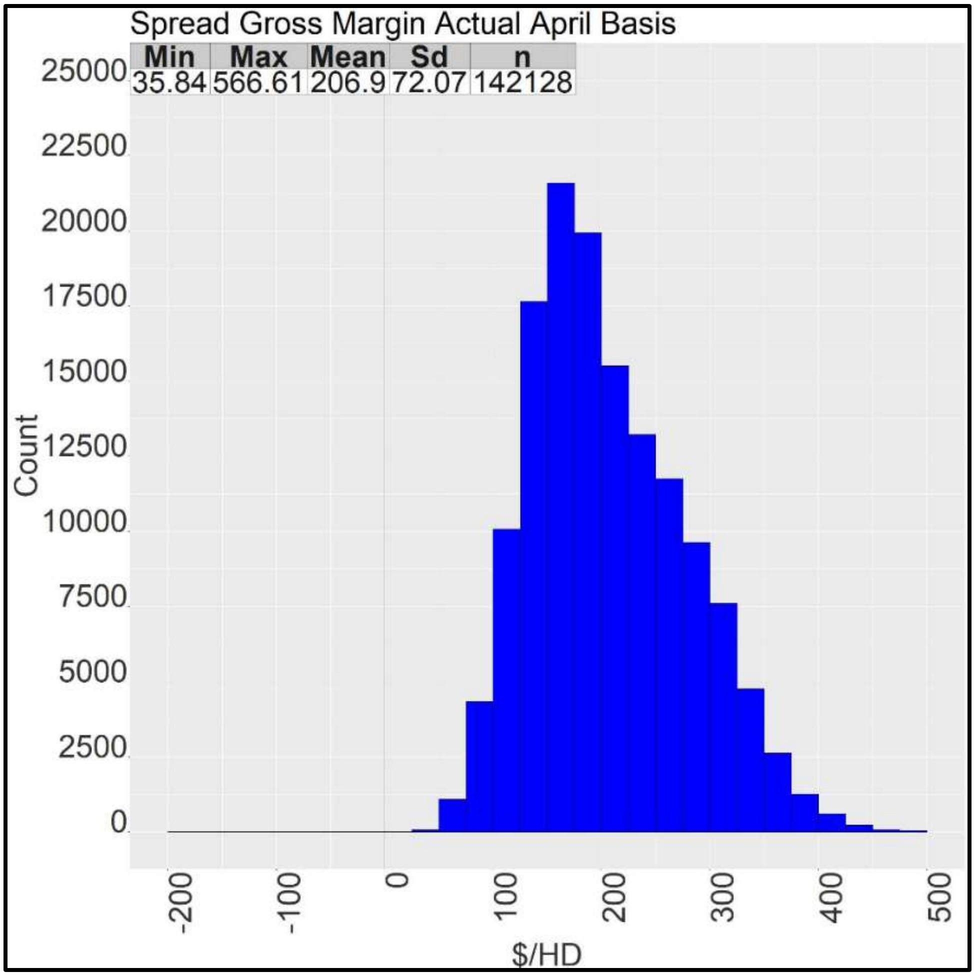

Figure 26: Spread Gross Margin Actual April Basis

from 2001-2010 ranged from $124.20/head to $195.48/head and averaged $160.60/head. Standard deviation ranged from $25.67/head to $35.66/head and averaged $29.94/head. The highest return and standard deviation occurred in the 2008 sale year and the lowest mean return occurring in 2006. In the 2011-2021 period, spread gross margin returns ranged from $209.16/head to $300.82/head and averaged $262.56/head. Standard deviation ranged from $36.09/head to $70.38/head and averaged $51.99/head. Spread gross margins exhibited the same relationship as cash, and hedge margins increasing in both level and volatility in the 2011-2021 period relative to the 2001-2010 period. Average gross margin returns from 2011-2021 were $101.96/head higher than 2001-2010 and average standard deviation increased $22.05/head.

Table 8: Spread Returns by Sale Year (Nov. – Mar)

Spread Returns by Sale Year NOV-MAR						
Year	**N**	**Mean**	**SD**	**Min**	**Max**	**Dif**
2001	6768	168.24	26.15	93.71	243.33	15.82
2002	6768	162.59	29.49	55.24	240.68	35.25
2003	6768	147.03	25.67	76.34	220.45	25.07
2004	6768	150.00	26.63	59.29	217.52	33.75
2005	6768	128.87	31.98	42.16	238.61	-28.19
2006	6768	124.20	29.13	52.46	229.49	18.53
2007	6768	151.99	31.73	58.76	247.00	-43.84
2008	6768	195.48	35.66	103.21	304.13	46.49
2009	6768	189.66	34.13	90.57	285.05	74.21
2010	6768	187.95	28.80	99.06	277.52	-58.63
2011	6768	209.16	36.09	103.19	329.12	-144.89
2012	6768	287.50	52.97	143.23	449.95	-95.30
2013	6768	297.70	45.98	129.02	442.87	94.64
2014	6768	250.76	47.10	140.13	486.59	-76.81
2015	6768	225.47	61.35	53.56	448.67	126.42
2016	6768	283.68	70.38	75.45	561.14	175.98
2017	6768	229.38	52.91	81.03	371.90	-59.82
2018	6768	273.75	52.54	100.85	458.09	54.47
2019	6768	268.19	50.27	140.46	416.63	43.50
2020	6768	300.82	49.32	144.56	426.80	118.15
2021	6768	261.79	52.96	110.21	445.90	-21.46
Total	**142128**	**214.01**	**72.03**	**42.16**	**561.14**	**15.87**

Figure 27 displays the distribution of spread gross margins by sale year using the November and March contracts. Although spread distribution increased in standard deviation in the 2011-2021 period, spread distributions are less volatile than cash or hedge returns. The reason for this change was not determined in this analysis and requires further research as to the origin of the change in market dynamics.

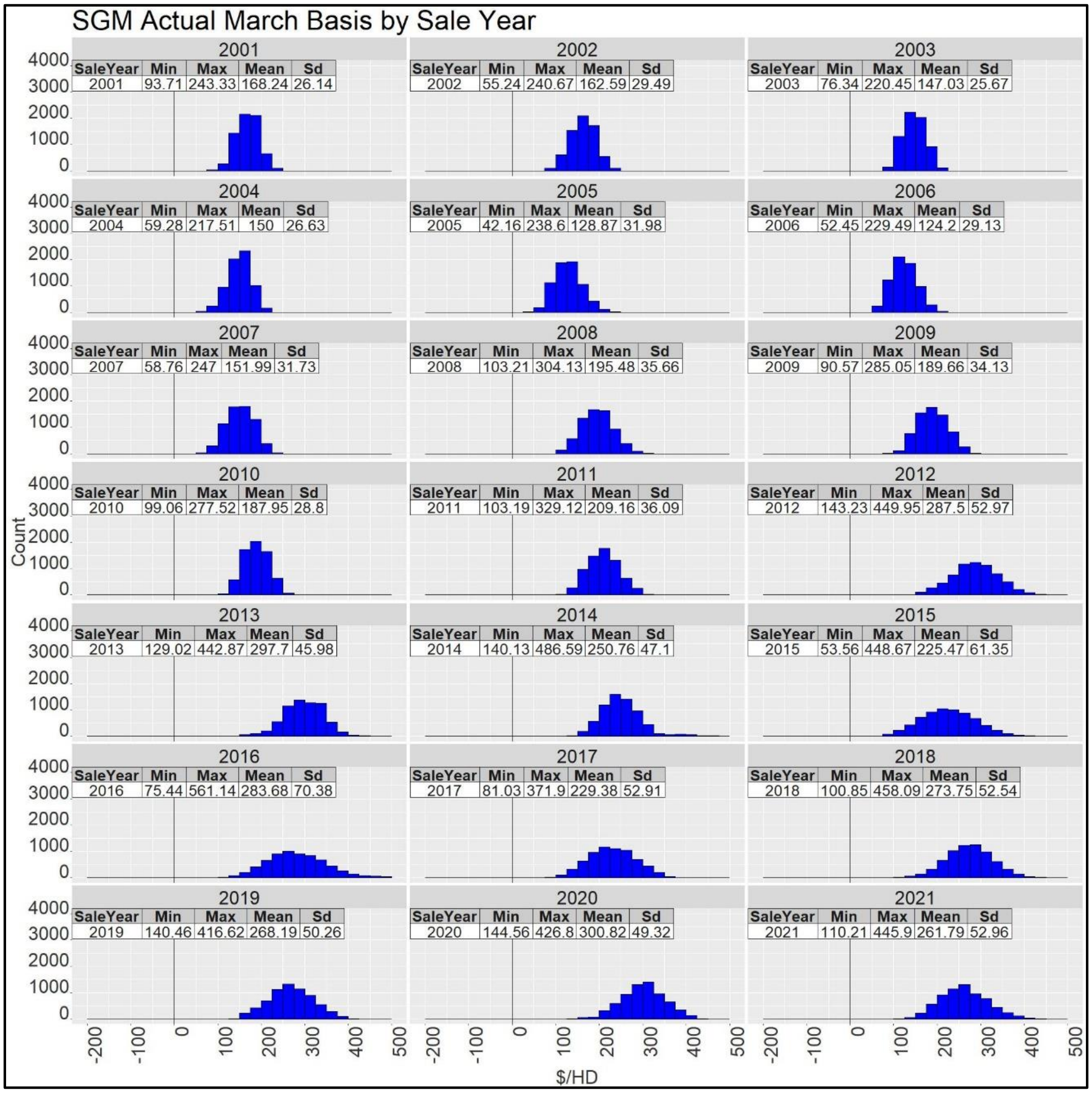

Figure 27: SGM Actual March Basis by Sale Year

5.4 Gross Margin Comparison by Type

Figure 28 illustrates that returns for cash, hedge, and spread returns followed a similar path over the 21 production years. The cash market generated higher returns when market prices were trending upward while hedge or spread returns generated higher returns when prices were moving lower. Each year included the average cash gross margin for all weight classes and the average hedge gross margin for every hedging opportunity for each cash observation. Average spread returns were significantly higher than cash or hedge returns in both 2015 and 2016. The spread return was higher in this period because both the purchase and sale of the cattle were hedged prior to adverse price moves in both the cash and futures markets. It does not appear that one strategy was unequivocally superior to any of the others indefinitely in this analysis. The producer must evaluate the differences between the separate marketing opportunities and determine the return and risk level that is best suited for their operation and preferences. Cash

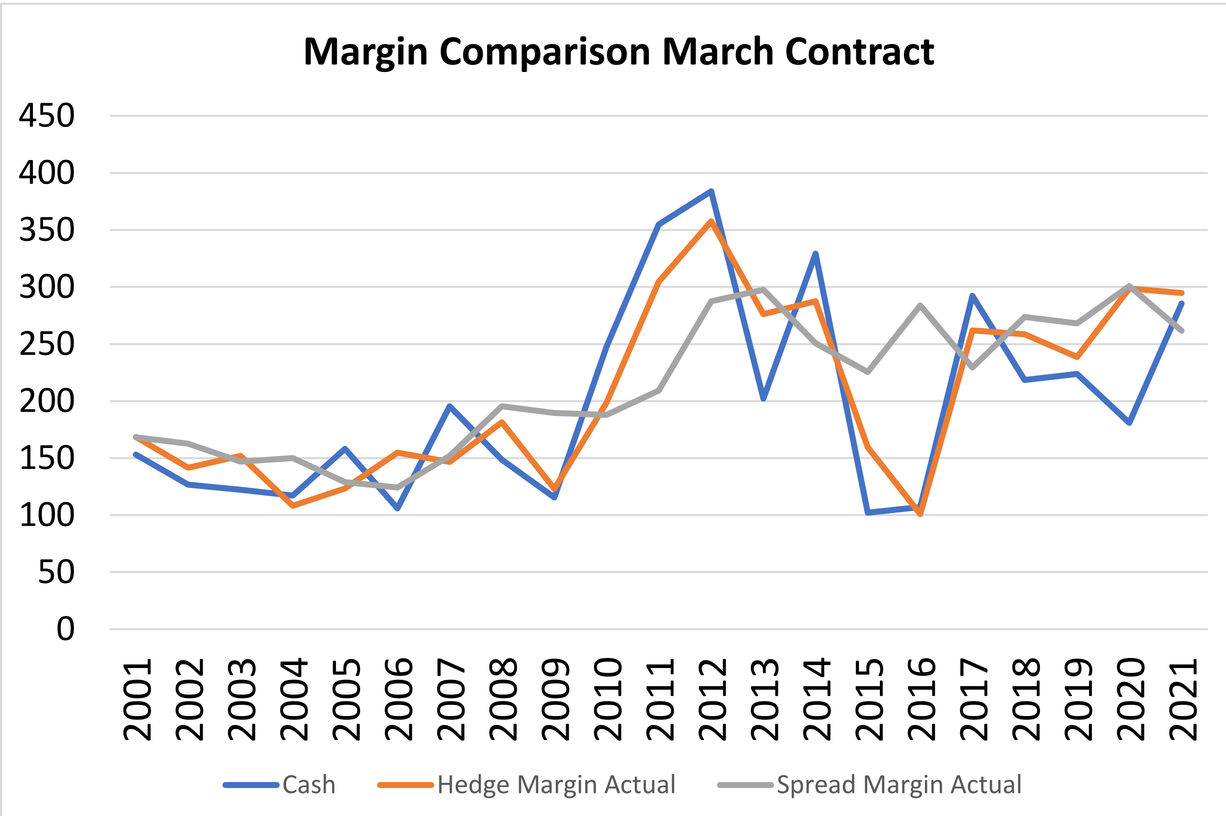

Figure 28: Margin Comparison March Contract

returns offered the highest highs, and lowest lows. Average spread margins limited upside return potential, but limited downside return potential. Average hedge returns were almost always intermediate to both cash and spread returns. Tradeoffs exist between the potential margin levels and risk levels each type of return offers.

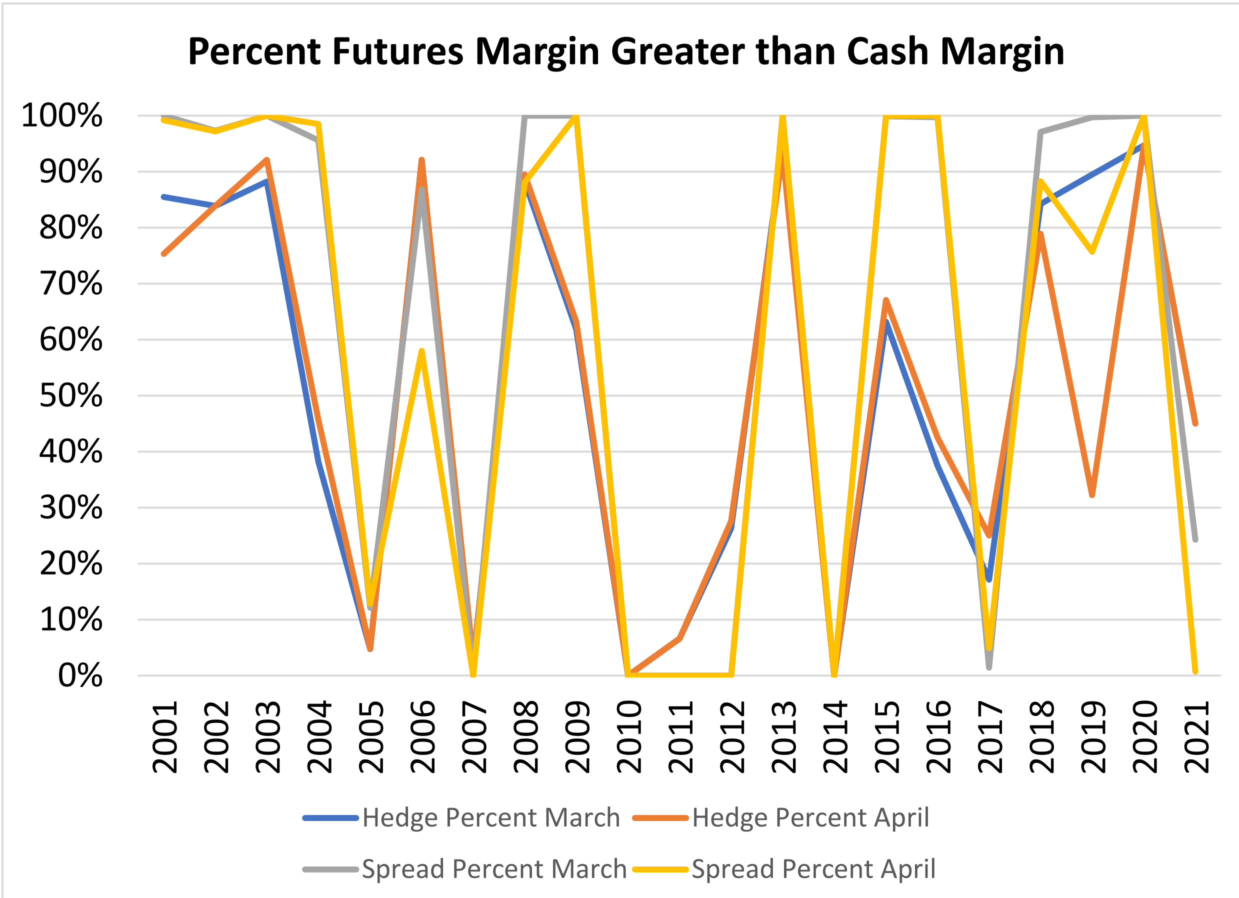

Figure 29: Percent Futures Return Greater than Cash

Figure 29 shows the percentage of hedge and spread that were greater than the average cash return for each sale year. Actual basis was used in the calculation to determine what the futures market offered from a forward margin perspective. There were years where forward prices using futures market always offered a higher average return than was achieved in the cash market. Conversely, there were years where the futures market never priced in a higher average return than was realized in the cash market. This chart does not consider margin calls should futures move against a position but shows the percentage of opportunities the hedger could have

Table 9: Return by Mean Value High to Low

	High	Middle	Low
2001	168	168	152
2002	163	142	127
2003	152	147	122
2004	150	116	108
2005	157	129	123
2006	155	124	106
2007	196	152	147
2008	195	181	149
2009	190	123	115
2010	247	198	188
2011	354	305	209
2012	383	358	288
2013	298	276	203
2014	328	287	251
2015	225	160	99
2016	284	108	101
2017	289	262	229
2018	274	259	219
2019	268	239	225
2020	301	299	183
2021	295	283	262

Cash
Hedge
Spread

achieved an average margin greater than the cash margin for every observation in a production year.

Table 9 ranks each type of return by mean value from high to low for each sale year. Cash returns were highest, middle, and lowest on average in 7, 3, 11 years, respectively. Hedge returns were highest, middle, and lowest on average in 4, 13, and 4 years, respectively. Spread returns were highest, middle, and lowest on average in 10, 5, and 6 years, respectively. Table 10 ranks each type of return by standard deviation of mean return by year. Cash return standard

Table 10: Standard Deviation Table

Standard Deviation Table			
Year	**Low**	**Middle**	**High**
2001	24.9	26.1	28.8
2002	28.8	29.5	29.7
2003	25.7	27.0	33.4
2004	26.6	28.8	40.7
2005	32.0	32.6	33.1
2006	29.1	29.9	37.0
2007	31.7	33.6	39.7
2008	34.4	35.7	39.8
2009	27.0	34.1	35.1
2010	28.8	31.5	37.2
2011	35.0	36.1	52.3
2012	47.9	53.0	57.5
2013	41.4	46.0	57.0
2014	47.1	47.8	51.1
2015	61.4	64.1	115.8
2016	64.4	70.4	83.2
2017	50.4	52.4	52.9
2018	52.5	61.9	63.6
2019	50.3	51.4	51.8
2020	49.3	68.6	73.0
2021	53.0	59.1	62.0

Cash
Hedge
Spread

deviation was the lowest, middle, and highest in 9, 11, and 1 year(s), respectively. Hedge return standard deviation was the lowest, middle, and highest in 0, 2, and 19 years, respectively. Spread return standard deviation was the lowest, middle, and highest in 12, 8, and 1 year(s), respectively. When mean return and standard deviation for each type of return were compared by year the spread trade was the highest return and lowest variance in the most years. Hedge returns was the second highest return in most years but had the highest standard deviation in the most years. Standard deviation of hedge returns was impacted by the complete evaluation of all hedging opportunities. There were hedge returns included in the calculation that a producer would be unlikely to accept in practice which decreased the mean return level for hedging and increased the standard deviation.

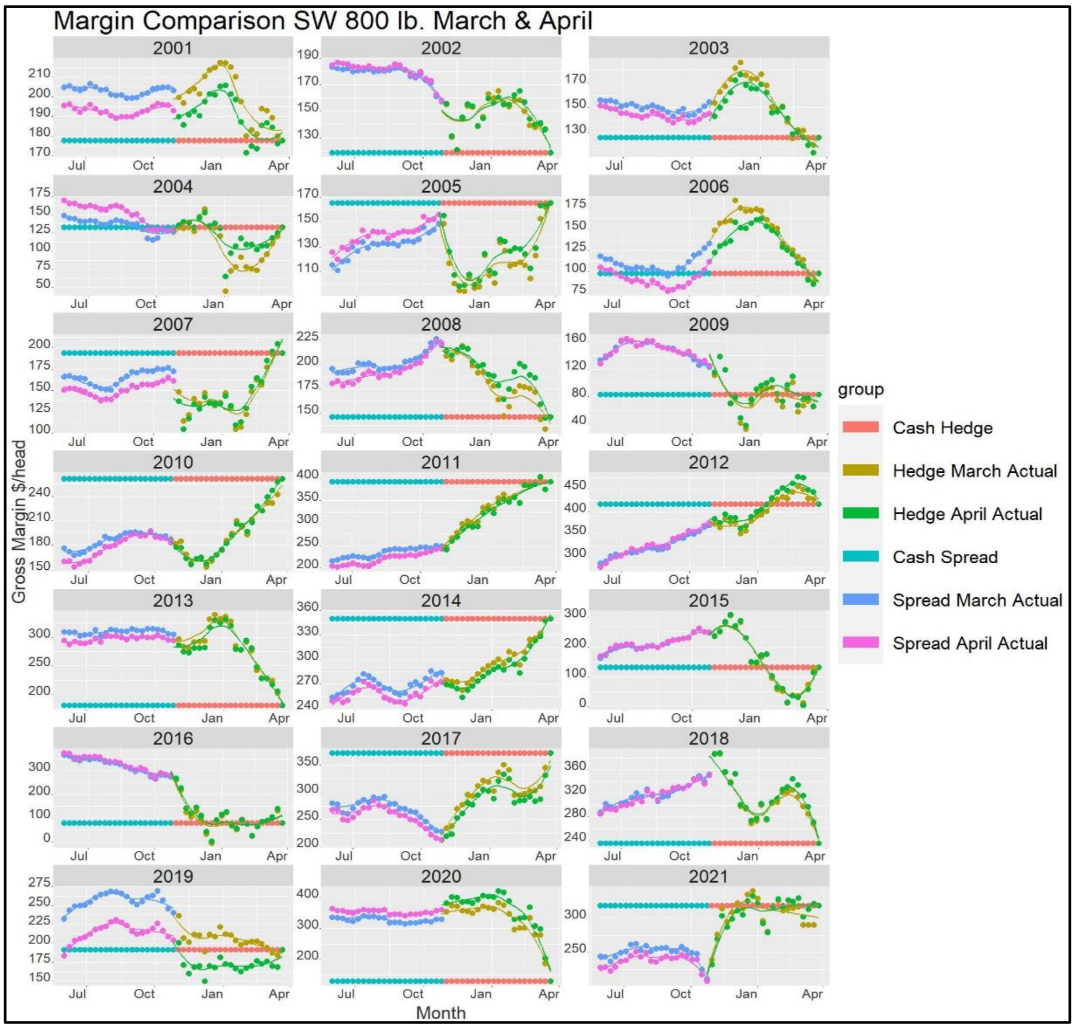

Figure 30: Season Pattern of Hedge and Spread Margins

Figure 30 illustrate the season pattern of hedge and spread margins from the first week the spread trade could have been placed until the last day the hedge trade could have been placed and demonstrates how both types of margins change in each production year for an 800 lb. steer.

The spread margin shows less variance compared to the hedge margin within the production year. The 2001 and 2019 sale years showed differences in returns between using the March or April contracts for both spread and hedge margins, but most years exhibited minute differences in margins between the two contracts.

5.5 Basis Model Results

Basis Regression Results				
Coefficients:	**Estimate**	**Std. Error**	**Pr(>|t|)**	
(Intercept)	**152.1000**	**4.4380**	**< 2e-16**	***
WT Class	**-0.3285**	**0.0117**	**< 2e-16**	***
WT Squared	**0.0002**	**0.0000**	**< 2e-16**	***
PDSI Value	**-0.0744**	**0.0371**	**0.0452**	*
CornClose	**0.0042**	**0.0008**	**0.0000**	***
Open Basis	**0.3758**	**0.0152**	**< 2e-16**	***
Purchase Week_F44	-0.1227	0.2411	0.6107	
Purchase Week_F45	**-0.4070**	**0.2407**	**0.0910**	.
Purchase Week_F46	-0.2657	0.2412	0.2709	
Sale Week_F10	0.3546	0.2408	0.1411	
Sale Week_F11	0.2787	0.2408	0.2473	
Sale Week_F12	**0.8531**	**0.2408**	**0.0004**	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: **4.392** on 2648 degrees of freedom
Multiple R-squared: **0.8491**, Adjusted R-squared: **0.8485**
F-statistic: **1355** on 11 and 2648 DF, p-value: **< 2.2e-16**

Figure 31: Basis Regression Results

Results of the basis regression are shown in Figure 31. All explanatory variables had statistically significant coefficients and two of the dummy variables had statistically significant coefficients. the model had an adjusted R squared value of 0.8485. Residuals were plotted against both sale year and weight class in Figures 32 and 33 respectively. The 2015 sale year had the widest residual error out of all other sale years. Most years exhibited a range in residual error that was within $10 plus or minus the actual basis. The model did not capture the differences in basis pattern that occurred in 2015.

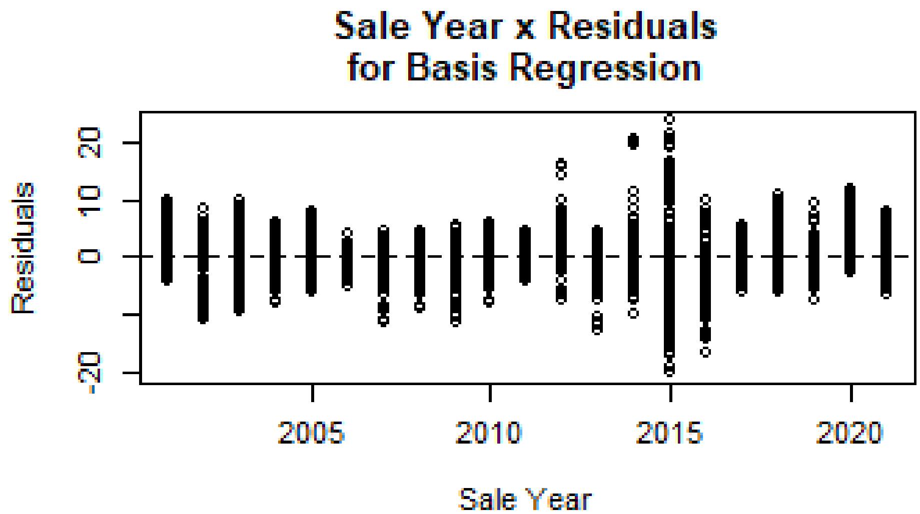

Figure 32: Residuals by Sale Year

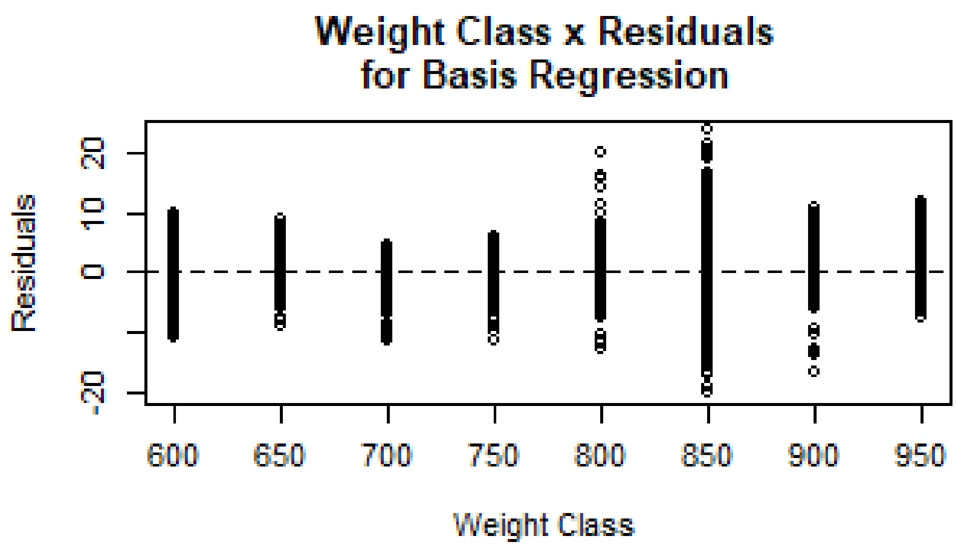

Figure 33: Residuals by Sale Weight

The 850 lb. weight class had the widest residual error out of all other weight class. This was unexpected because basis was shown to be more variable for weight classes that were in the

600-650 lb. and 900-950 lb. range. Basis predictions for the weight classes further from 800 lbs. was expected to have larger residuals the weight classes near the specification of the feeder cattle futures contract. The reason for the difference between expectations and results was not determined and warrants further analysis.

Figure 34 shows the sum of squared errors of gross margin predictions for the historic basis types and model predicted basis used in the hedge analysis relative to the hedge gross

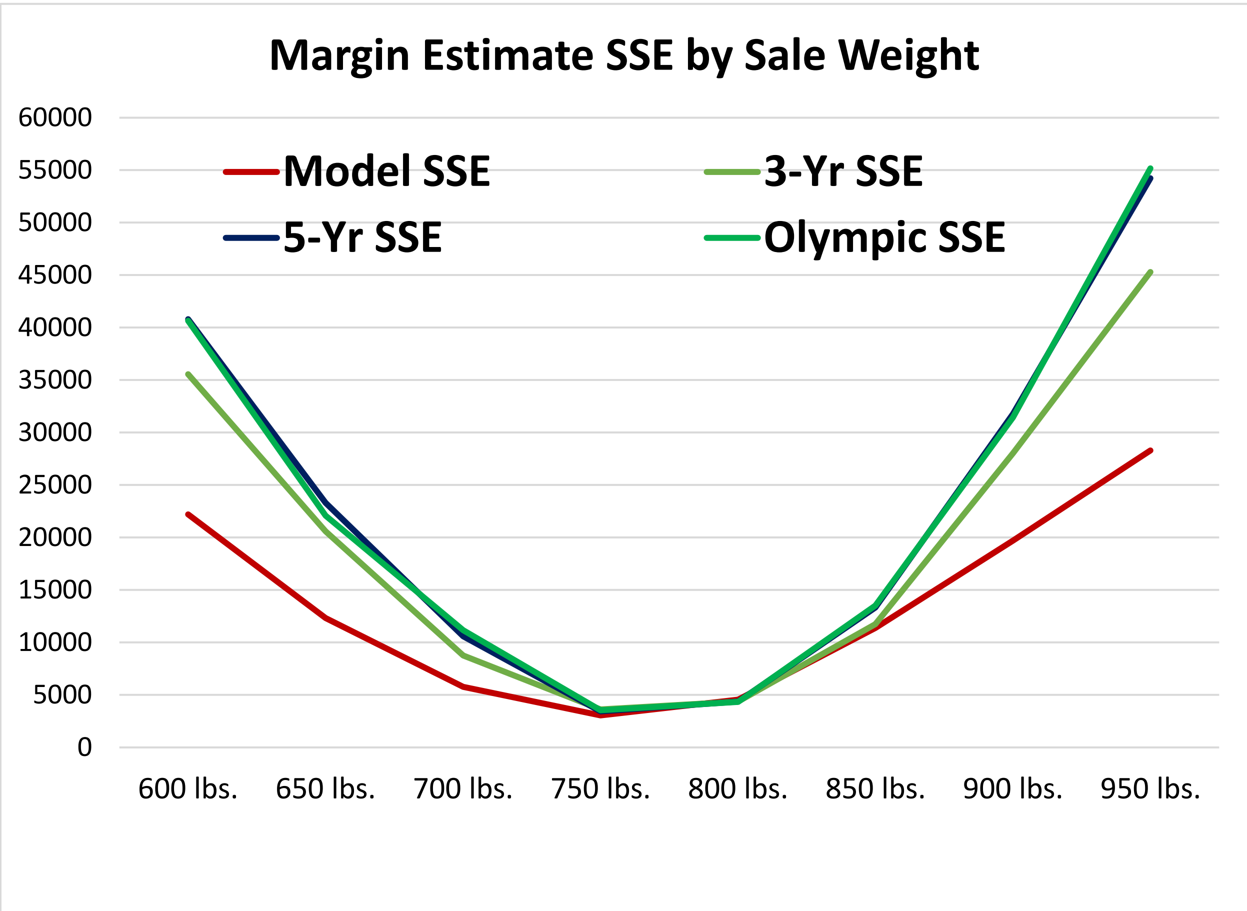

Figure 34: Sum of Squared Error of Predicted Margin

margin predicted by the actual basis. Historic and model hedge margin estimates were compared to the actual hedge margin to rank the effectiveness of each basis at estimating the true basis that was used to generate gross margins. A larger sum of squared error indicated the predicted value of gross margin was further from the true hedge gross margin that used the actual basis. The model predicted basis SSE was lower, and therefore more effective, at predicting the actual gross margin than the 3-year, 5-year, and Olympic basis margins. for the 600 lb., 650 lb., 700 lb., 900 lb., and 950 lb. sale weight classes. For the 750 lb., 800 lb., and 850 lb. weight classes there was little difference in SSE between the basis types used to predict the actual gross margin. The results indicate that the basis model developed in this study was more effective at predicting actual basis than historic basis estimates for most sale weights included in the analysis.

CHAPTER 6: CONCLUSIONS AND IMPLICATIONS

Feeder cattle markets have faced volatile price patterns and production challenges over the last two decades. The volatile market environment has increased the uncertainty in returns for stocker operators. The objective of this analysis has been to quantify cash, hedge, and spread gross margins over a two-decade span and communicate market dynamics and differences in marketing methods and risk management opportunities to stocker operators. Furthermore, this analysis analyzed basis patterns of various sale weights within the production year and examined differences in weekly basis estimates and the effectiveness of estimating actual basis using a 3-year average, 5-year average, 5-year Olympic average, and model predicted basis.

This analysis focused on scenarios that aligned with Oklahoma pure stocker operation in a dual-purpose winter wheat scenario and assumes cattle of various weight classes will be purchased in the fall and sold in the early spring. Returns were only calculated for the stocker sector and did not include returns from wheat production. Scenarios for this analysis included steer prices for six purchase weights that ranged from 400-650 lbs., three amounts of gain that ranged from 200-300 lbs., eight sale weights that ranged from 600-950 lbs., and 16 marking windows that included four purchase weeks that aligned with the last two weeks in October and the first two weeks in November, and four sale weeks that aligned with the last two weeks in February and the first two weeks in March across 21 production years.

6.1 Gross Margin and Basis

The primary conclusion of this analysis is that mean returns have increased in level but become more volatile in the 2011-2021 period in comparison to 2001-2010 period. This has been shown to be true across cash returns, forward hedge returns, and forward spread returns. Mean cash margins from 2001-2010 were $148.75/head and mean cash margins from 2011-2021 were $243.03/head. Mean hedge margins for the March contract from 2001-2010 were $149.77 /head and mean hedge margins from 2011-2021 were $258.10/head. Mean hedge margins for the April contract from 2001-2010 were $148.21/head and mean hedge margins from 2011-2021 were $255.45/head. Mean spread margins for the November and March contracts from 2001-2010 were $160.60 /head and mean hedge margins from 2011-2021 were $262.56/head. Mean spread margins for the November and April contracts from 2001-2010 were $154.39/head and mean hedge margins from 2011-2021 were $254.65/head.

Standard deviation of cash margins from 2001-2010 were $29.84/head and standard deviation of cash margins from 2011-2021 were $54.22/head. Standard deviation of hedge margins for the March contract from 2001-2010 were $35.43 /head and standard deviation of hedge margins from 2011-2021 were $65.02/head. Standard deviation of hedge margins for the April contract from 2001-2010 were $34.22/head and standard deviation of hedge margins from 2011-2021 were $65.81/head. Standard deviation of spread margins for the November and March contracts from 2001-2010 were $29.94 /head and standard deviation of spread margins from 2011-2021 were $51.99/head. Standard deviation of spread margins for the November and April contracts from 2001-2010 were $30.28/head and standard deviation of spread margins from 2011-2021 were $52.52/head.

Risk has increased for all types of returns, and no marketing method was unequivocally superior to its alternatives. There was not a marketing method that always offered the highest mean return, however the spread method most frequently exhibited the lowest variance of returns across the production years. Cash market participation offers the highest mean return in some years and the lowest mean return in others. Spread returns had the lowest standard deviation of return in 19 of the 21 sale years but often limited the upside and downside gross margin potential that could have been obtained by selecting other marketing methods. Spread margins evaluated for each sale year were also the highest average return in 10 of the 21 years. Hedge margins most often expressed the highest standard deviation in returns across all years except for two and was most frequently the second highest average return.

Differences between using the March and April feeder cattle futures contract for both hedge and spread margins were minute for the production scenario in this study. The two contracts offered similar average returns and risk levels for both the hedge and spread trades.

Examining the seasonal pattern of the hedge and spread margin within each production year demonstrated that some years offered a hedge or spread return that was greater than the cash margin received at the end of the production years while other years never offered a hedgable return that was greater than the cash margin. The optimal time to place a hedge or execute the spread trade varied considerably between production years indicating that the optimal time to place a hedge or spread trade do not exhibit seasonal patterns but are dependent on each year's market environment. However, there are potential signals derived from the within year changes of hedge and spread margins that may indicate when a hedge or spread should be executed. These signals warrant further evaluation and investigation to determine their reliability.

Basis was shown to have a seasonal pattern within each production year. Basis tended to strengthen for lighter weight class from the fall to spring. Basis tended to remain neutral or weaken for middle and heavier weight classes from the fall to spring. Basis patterns are likely a function of supply levels of different weight classes at different times of the year. Volumes of lighter weight classes tend to be larger in the fall in comparison to the spring. Conversely, volumes of heavier weight classes tend to be larger in the spring in comparison to the fall.

The effectiveness of using historic basis to estimate actual basis varied between years and weight classes. Historic basis estimates were most effective at predicting actual basis for weight classes nearest 800 lbs. For weight classes that were lighter or heavier than 800 lbs. basis error increased for the historic basis estimates. The basis model developed in this analysis to estimate actual basis decreased basis error and performed better than all historic basis estimates for all weight classes except the 850 lb. weight class. The 3-year average basis had a slightly lower SSE for the 850 lb. weight class than the model predicted basis.

6.2 Limitations and Further Research

This analysis provides insight of gross margin returns to the stocker sector of the last 21 years. The results in this analysis hinge on the assumption that animals perform as assumed in terms of gain across all weight classes and all years. Furthermore, the study assumes that cattle are marketed at known purchase and sale weights. The study was conducted in this manner to capture the average return available across years for the winter wheat grazing production scenario. However, there are factors of stocker production this analysis was not able to include.

This analysis has not determined the reasons for the change in volatility of returns over the last 21 years. Determining the market factors that have increased the risk and uncertainty in the stocker cattle sector is of interest for further research. Potential risk drivers in the stocker cattle sector that may have influenced this change include the impact of drought on cattle supplies and the overarching cattle cycle and increased volatility in grain prices (Peel D. S., 2006).

Additionally, the analysis does not capture differences in animal performance between years and the influence of performance on gross margin returns. Animal performance varies between years and is influenced by forage quality and availability, and individual producer production practices. Forage quality and availability varies between years and is largely influenced by precipitation and drought conditions. In years where drought was prevalent, cattle may not have performed as assumed in this study and gross margins reported in this study would not account for these specific differences.

Future research may include applying a similar framework from this study to different production scenarios. Evaluating gross margin returns for summer grazing or different production regions may yield different gross margin levels and market dynamics. The stocker cattle are purchased throughout the year and evaluating and comparing margins from different production scenarios would inform producers of the characteristics of different markets from both a margin and basis perspective. Analyzing different risk management strategies such as options or the Livestock Risk Protection program would expand the information available to producers when selecting a risk management strategy. Moreover, the results of this analysis could be applied to an optimization framework specific to an individual producers' resources and constraints.

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APPENDIX

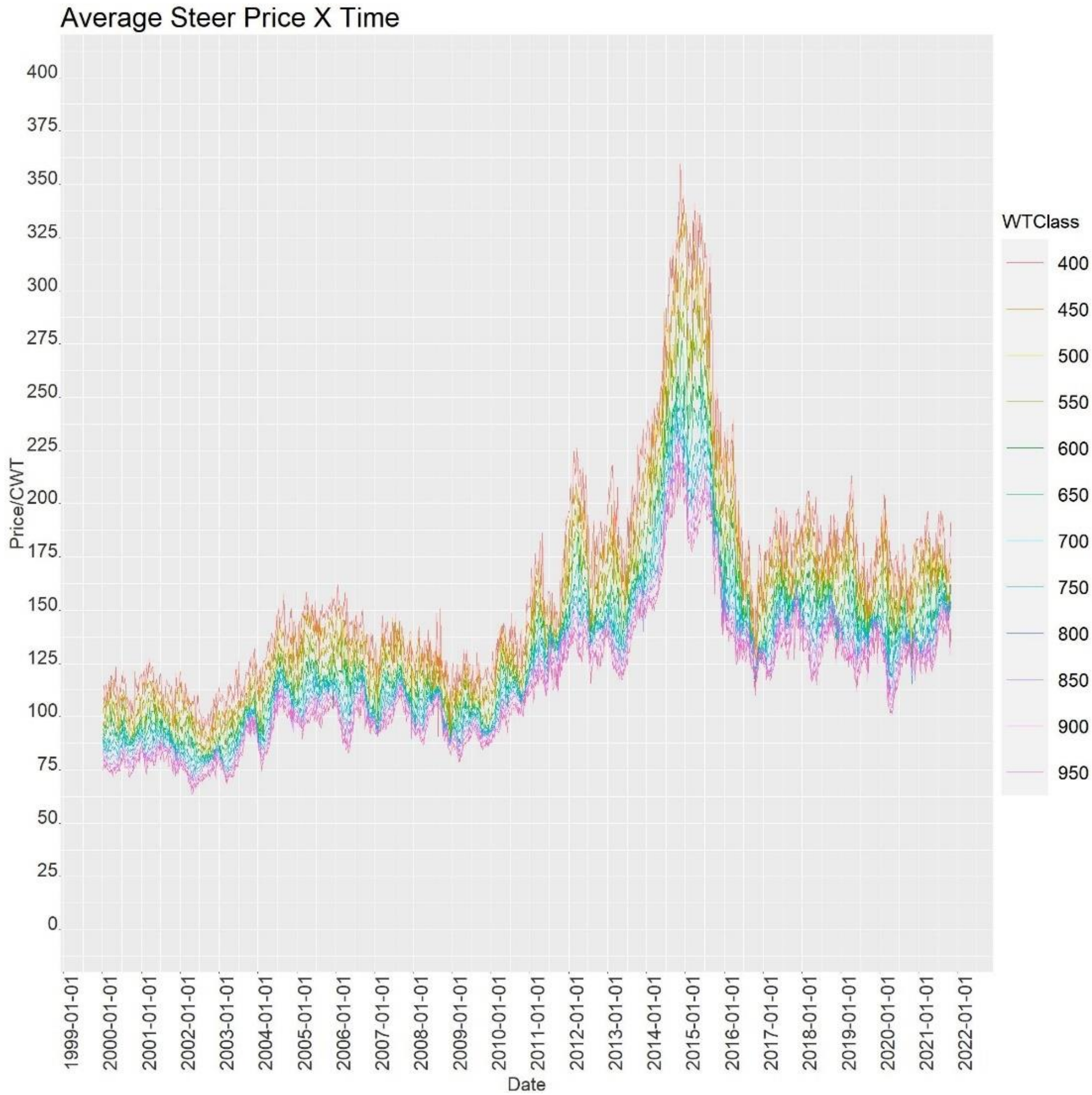

Figure 35A: Average Steer Price X Time

Sale Weight		2001 (N=288)	2002 (N=288)	2003 (N=288)	2004 (N=288)	2005 (N=288)	2006 (N=288)	2007 (N=288)	2008 (N=288)	2009 (N=288)	2010 (N=288)	2011 (N=288)
600												
	Mean	145.695	121.94	107.419	116.734	134.922	128.732	168.208	148.709	117.332	200.435	346.367
	SD	22.766	21.527	31.551	19.106	16.529	15.493	34.962	10.143	24.358	17.574	18.32
	Min	103.963	76.545	65.212	83.119	105.145	105.602	112.181	132.83	77.654	167.696	316.426
	Max	188.483	153.033	169.841	150.779	158.626	155.708	219.2	163.829	164.16	231.671	379.68
650												
	Mean	148.761	133.135	115.959	125.151	142.4	125.67	189.97	166.237	109.923	222.795	347.035
	SD	21.555	15.853	27.239	22.348	30.448	24.48	34.256	23.928	27.445	18.881	34.176
	Min	116.922	103.769	71.696	81.02	75.837	86.086	127.955	123.405	62.674	178.982	285.408
	Max	197.932	157.323	170.728	164.423	198.042	158.368	261.273	207.558	167.005	254.92	397.847
700												
	Mean	157.711	136.517	127.121	126.95	160.725	121.778	195.371	172.107	122.284	241.192	346.385
	SD	21.588	30.716	30.164	30.741	34.289	31.951	38.093	36.743	30.945	34.846	41.448
	Min	122.443	60.733	81.085	68.83	87.368	55.925	115.101	100.827	66.876	166.124	287.798
	Max	206.48	187.414	194.667	190.105	234.537	175.879	274.527	239.148	194.28	304.299	428.781
750												
	Mean	156.02	135.308	119.248	118.759	154.602	95.538	196.413	154.483	103.881	245.915	346.989
	SD	19.087	27.779	24.433	28.47	38.809	26.981	32.783	33.291	29.018	29.904	30.753
	Min	126.676	79.874	72.693	64.494	74.093	37.667	130.945	103.584	37.638	193.325	294.626
	Max	191.842	194.613	178.339	181.697	253.994	151.989	256.938	213.849	162.141	320.294	401.956
800												
	Mean	156.772	122.957	123.027	114.229	152.325	100.197	194.321	143.923	111.049	242.421	353.305
	SD	28.621	22.357	22.122	24.525	26.458	25.605	34.525	32.798	25.022	17.068	28.964
	Min	109.39	64.735	84.846	72.319	100.719	43.831	128.939	91.628	72.084	199.348	305.479
	Max	226.001	161.325	173.032	169.499	205.621	151.156	278.022	222.205	167.148	274.221	416.333
850												
	Mean	141.732	116.239	117.77	100.678	159.596	96.483	195.01	126.069	113.963	256.502	349.07
	SD	32.296	35.53	29.516	35.438	31.575	29.925	31.323	35.12	24.357	27.588	33.043
	Min	89.418	39.757	69.003	27.996	90.222	36.388	131.662	65.444	65.995	207.9	268.323
	Max	200.508	167.902	176.897	159.338	220	150.116	255.499	189.903	166.886	310.962	406.599
900												
	Mean	151.257	120.747	128.57	111.571	168.348	92.183	205.781	135.482	124.938	272.777	378.273
	SD	20.562	32.163	25.319	26.691	29.475	25.423	22.782	27.2	15.887	18.443	36.752
	Min	121.972	58.262	88.071	71.058	104.193	56.821	160.705	90.143	91.86	240.658	301.389
	Max	180.817	173.319	183.468	146.357	207.546	146.111	244.138	186.068	152.75	308.466	448.135
950												
	Mean	161.123	129.374	137.171	120.465	188.861	95.535	221.833	139.874	137.51	288.777	388.615
	SD	18.564	27.05	15.797	15.206	11.412	23.194	16.311	15.724	18.59	7.632	19.671
	Min	129.23	87.711	110.851	89.366	170.131	67.355	192.525	115.362	108.47	274.574	347.411
	Max	189.188	183.306	161.66	140.713	210.261	145.653	248.623	169.999	162.607	303.613	413.378

Sale Weight		2012 (N=288)	2013 (N=288)	2014 (N=288)	2015 (N=288)	2016 (N=288)	2017 (N=288)	2018 (N=288)	2019 (N=288)	2020 (N=288)	2021 (N=288)	Total (N=6048)
600												
	Mean	387.253	197.739	301.835	126.228	194.362	259.589	224.712	205.618	229.987	252.352	196.008
	SD	41.13	39.259	28.779	62.018	59.027	34.843	37.477	56.585	62.31	29.653	84.6
	Min	338.291	149.521	252.099	3.892	107.229	217.401	165.461	135.875	108.667	197.759	3.892
	Max	479.397	260.628	358.137	220.796	286.666	316.129	295.345	330.991	303.755	295.417	479.397
650												
	Mean	385.243	188.287	309.39	135.375	145.98	273.383	237.047	195.754	222.151	259.353	199
	SD	46.711	54.823	32.086	67.693	70.806	47.007	44.036	54.222	67.174	44.656	87.39
	Min	292.829	86.455	254.476	2.367	42.739	174.947	168.155	115.401	76.359	176.453	2.367
	Max	488.536	310.825	381.918	275.809	299.854	343.759	343.205	328.625	325.55	328.558	488.536
700												
	Mean	391.372	199.054	356.293	109.692	125.125	296.329	259.996	207.963	211.545	264.813	206.206
	SD	50.395	51.847	78.065	72.286	80.637	52.951	50.291	61.178	68.904	56.942	96.793
	Min	302.231	122.038	219.109	-55.573	-15.813	201.606	150.641	112.018	58.141	155.844	-55.573
	Max	507.971	332.224	542.889	244.817	322.788	389.45	368.831	375.116	334.687	363.971	542.889
750												
	Mean	392.531	206.31	311.732	81.424	107.624	284.846	231.545	205.46	196.532	279.322	196.404
	SD	44.02	34.444	41.263	76.833	47.667	54.374	52.412	40.256	62.578	62.89	95.353
	Min	304.36	138.031	234.509	-80.772	35.689	176.537	108.314	117.373	68.019	159.652	-80.772
	Max	483.058	271.27	390.521	224.091	210.144	410.944	333.127	310.349	314.02	387.873	483.058
800												
	Mean	399.371	200.291	317.469	92.702	84.716	280.531	212.023	226.09	166.076	276.259	193.812
	SD	41.717	29.805	35.034	65.967	38.707	46.435	57.277	32.723	66.109	63.193	95.971
	Min	330.908	140.198	247.844	-20.597	21.112	198.48	100.183	158.679	48.432	169.592	-20.597
	Max	493.131	272.82	393.094	265.192	178.117	394.707	327.9	298.38	323.733	419.626	493.131
850												
	Mean	369.365	196.683	327.766	74.428	75.07	286.132	197.097	238.413	147.31	297.553	189.663
	SD	54.245	36.795	36.123	43.236	51.141	51.754	72.91	36.81	72.138	58.558	100.354
	Min	252.602	125.782	267.45	3.982	-46.552	173.678	20.733	167.909	-2.368	206.578	-46.552
	Max	458.586	269.063	391.679	177.008	165.057	409.64	349.611	308.692	280.77	451.532	458.586
900												
	Mean	362.768	219.676	336.837	96.263	91.727	314.175	183.088	262.501	149.815	320.22	201.286
	SD	42.686	39.205	25.973	39.338	51.095	40.883	65.894	40.644	66.654	47.566	100.673
	Min	290.073	138.885	294.588	34.31	-20.083	229.196	24.562	184.443	17.986	233.169	-20.083
	Max	430.698	279.445	383.699	193.241	183.804	390.578	298.108	356.954	256.291	411.668	448.135
950												
	Mean	349.303	234.394	362.251	118.559	91.32	327.385	179.969	288.537	149.865	333.064	211.609
	SD	32.517	17.896	20.488	17.53	41.541	36.754	52.69	34.768	71.968	38.66	99.557
	Min	278.458	210.736	326.142	90.597	28.492	267.803	75.842	228.112	30.862	264.635	28.492
	Max	388.175	265.9	391.379	149.698	158.738	402.111	276.881	348.479	236.968	390.701	413.378

Figure 36A: Table of Weights & Statistics

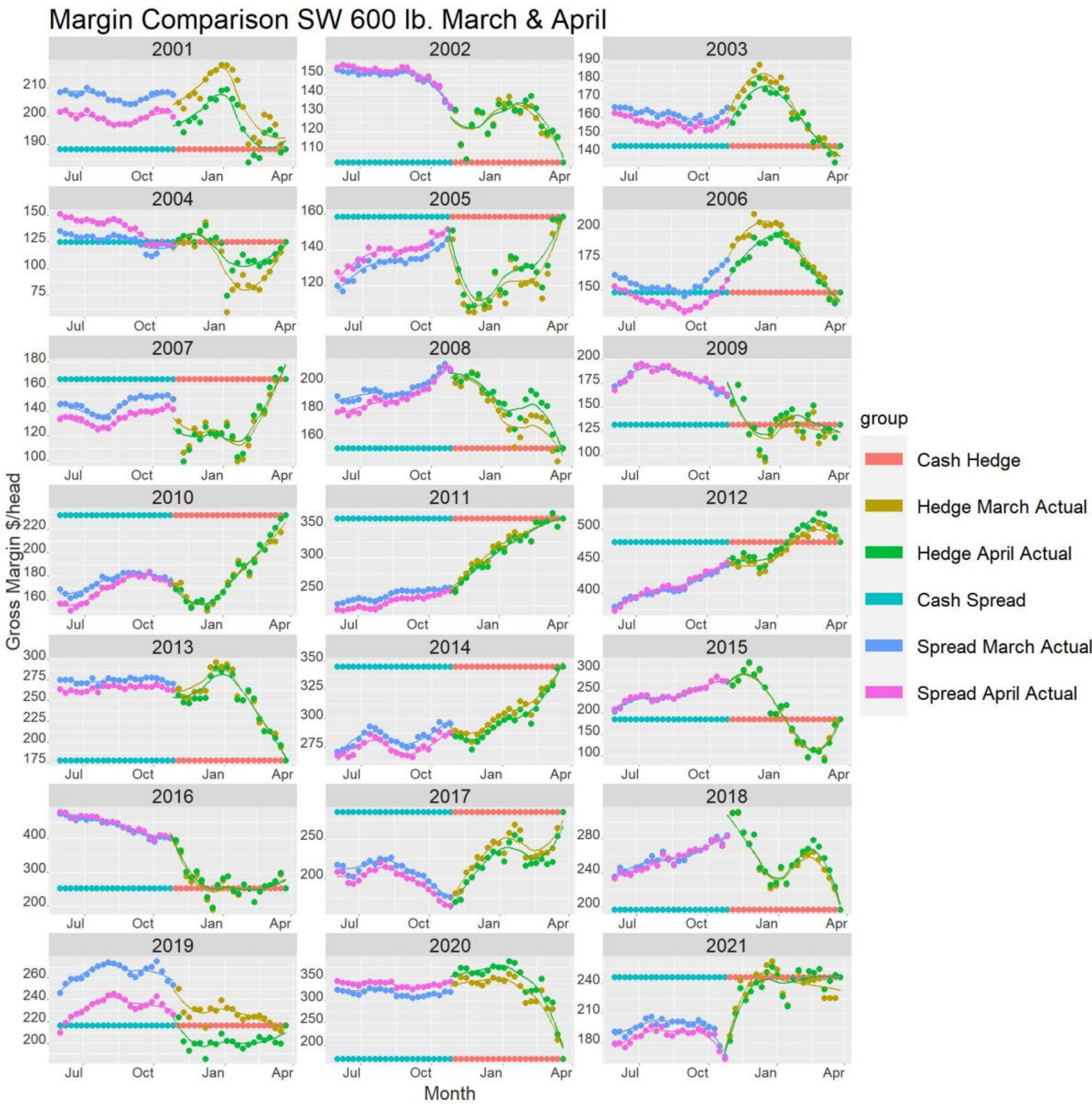

Figure 37A: Margin Comparison SW 600 lb.

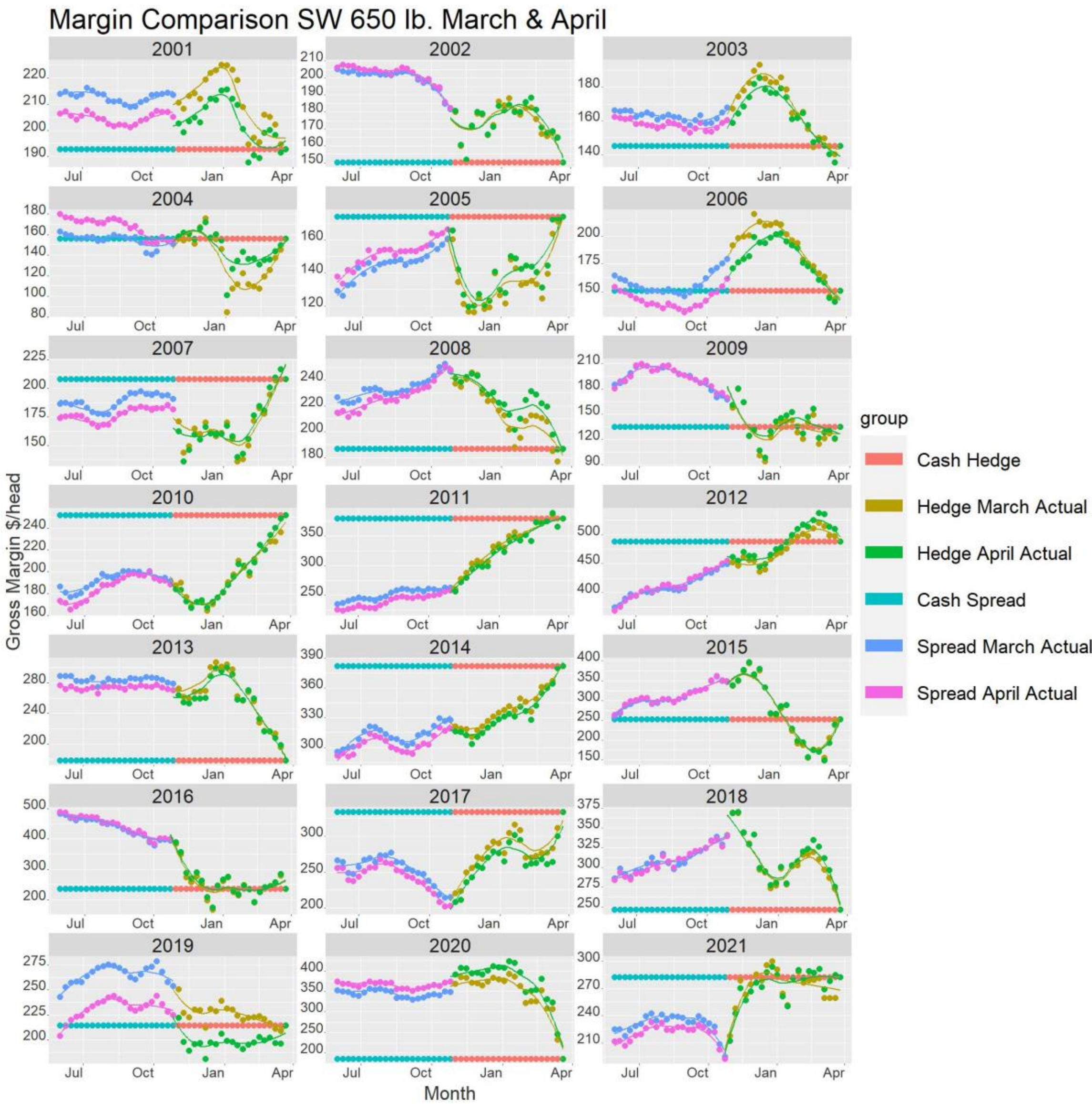

Figure 38A: Margin Comparison SW 650 lb.

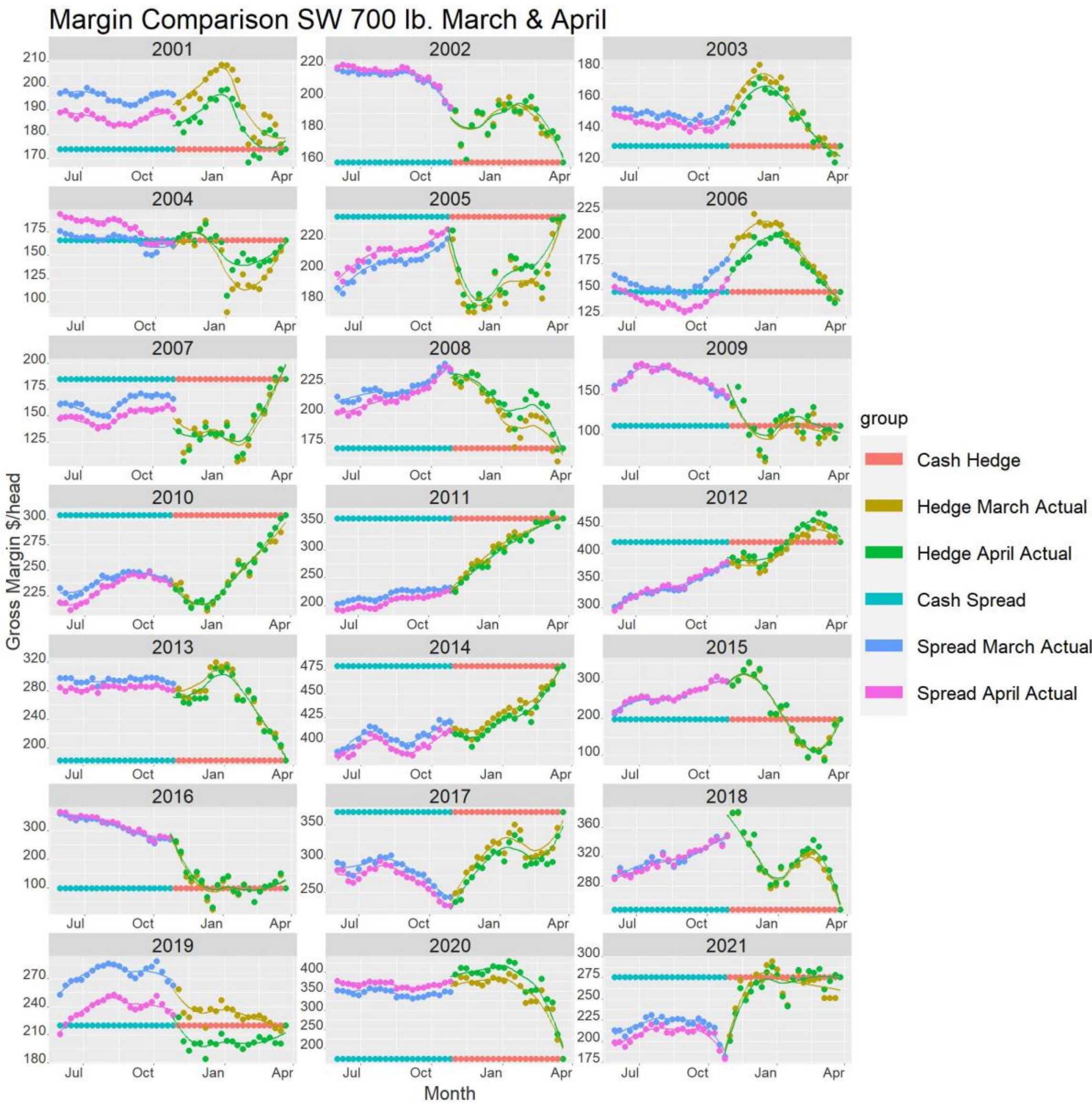

Figure 39A: Margin Comparison SW 700 lb.

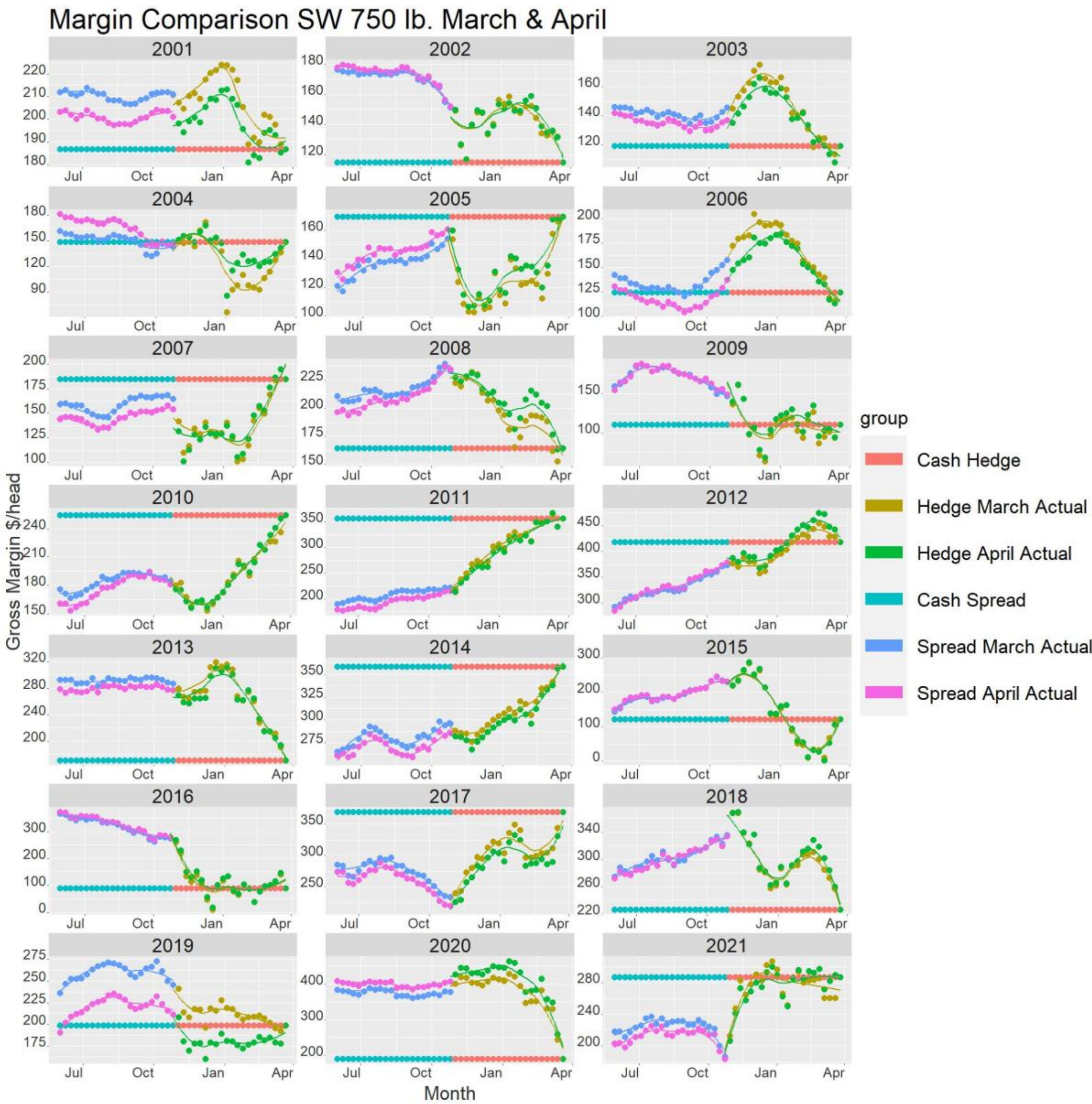

Figure 40A: Margin Comparison SW 750 lb.

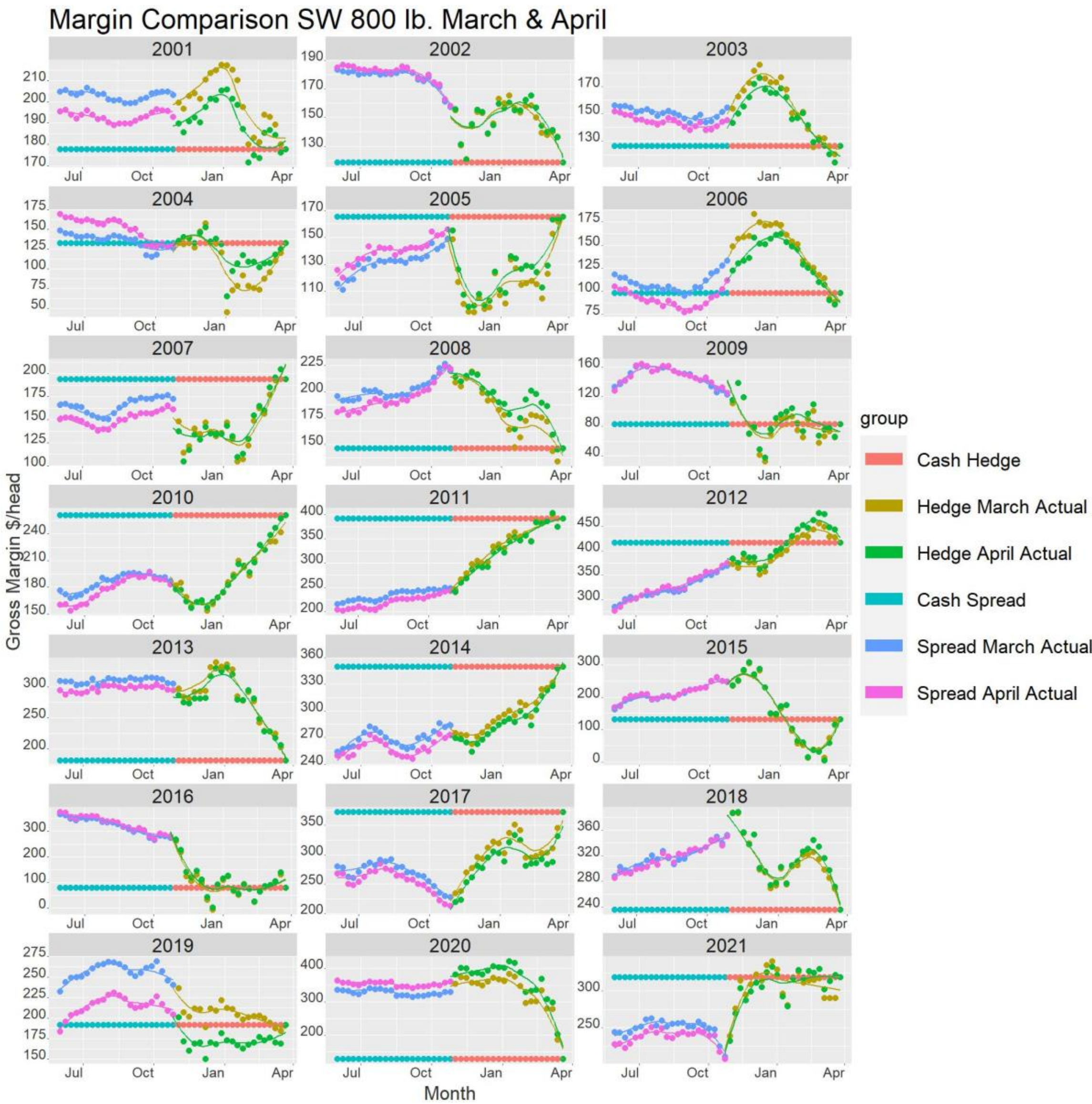

Figure 41A: Margin Comparison SW 800 lb.

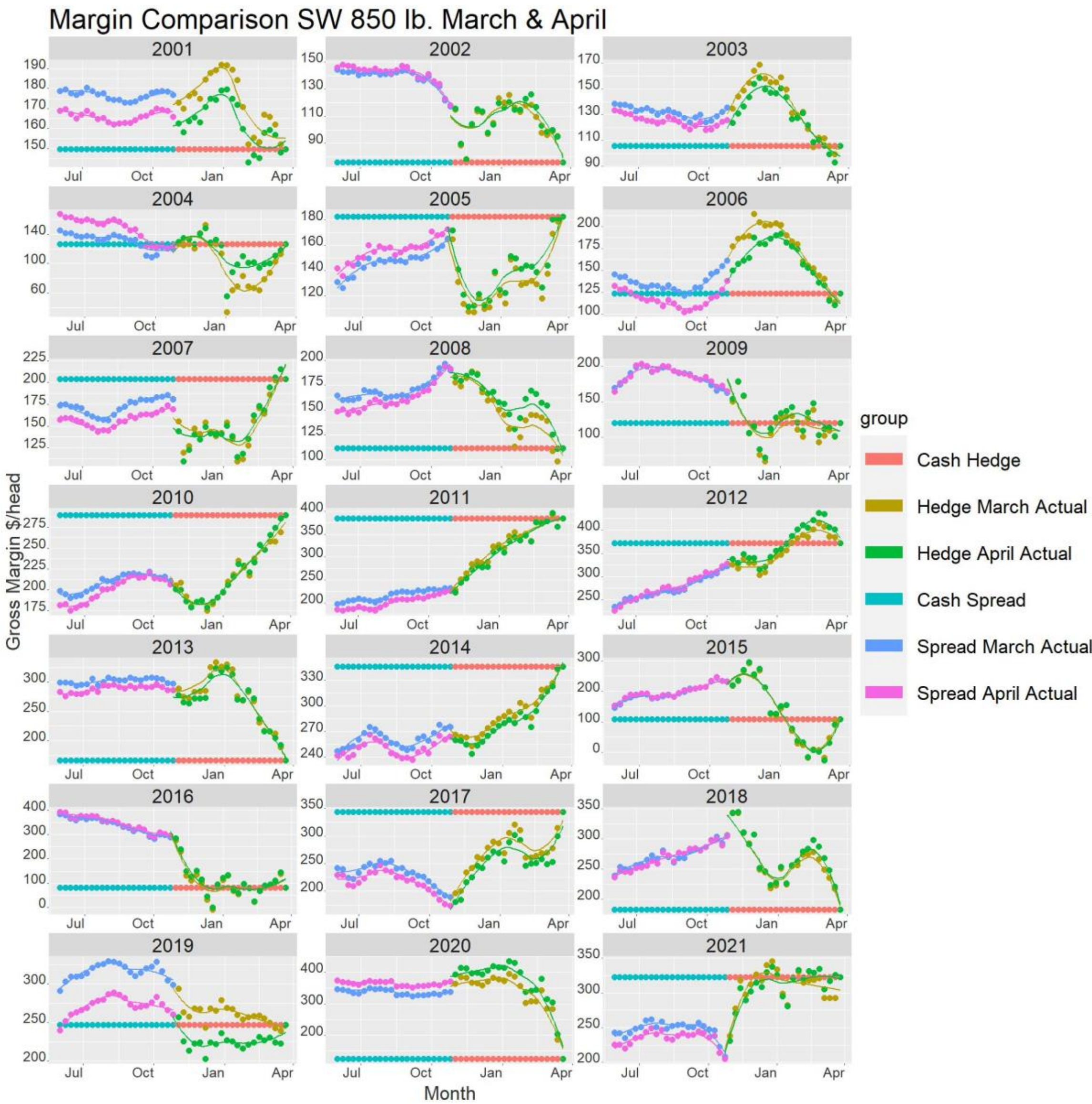

Figure 42A: Margin Comparison SW 850 lb.

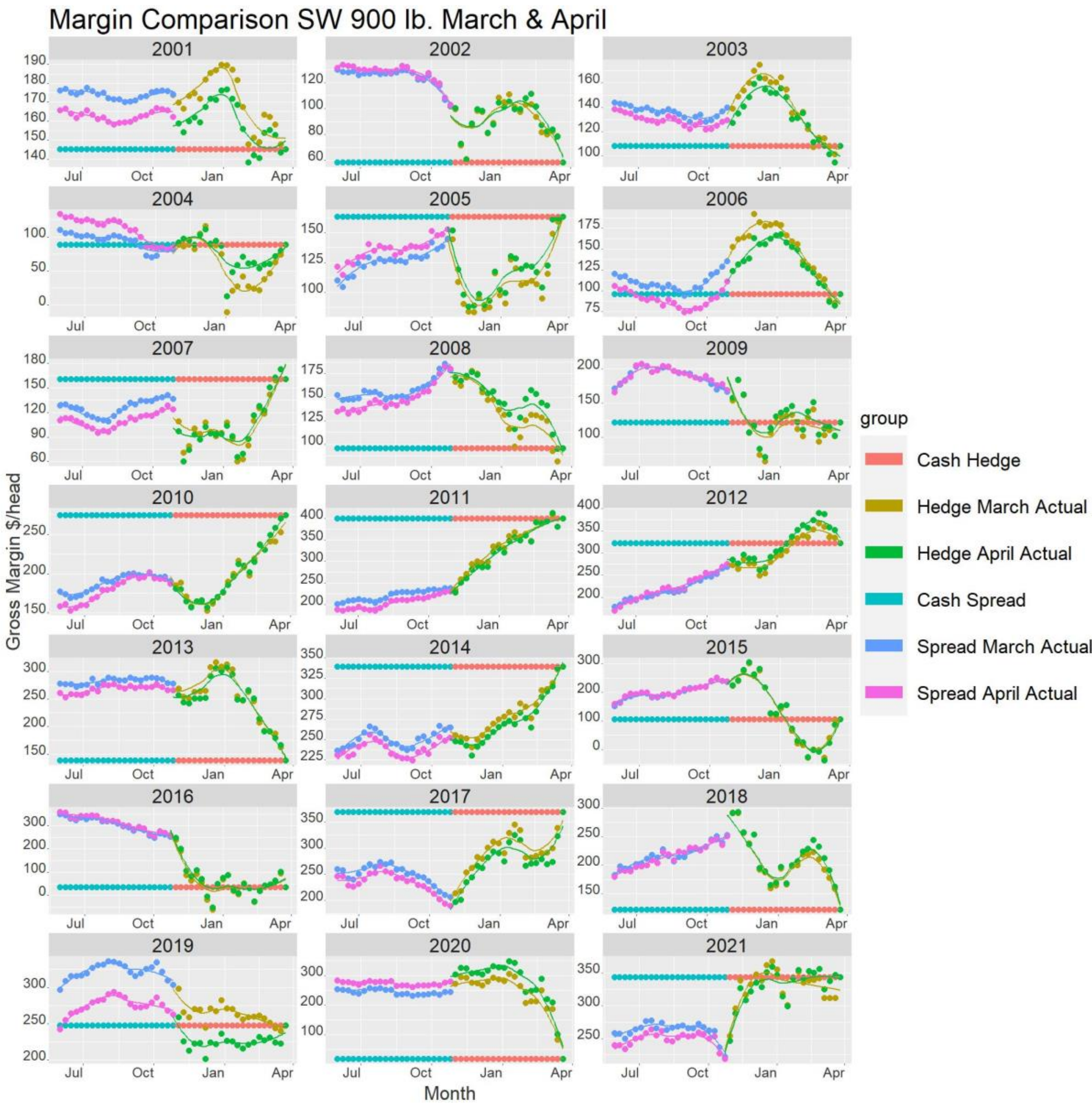

Figure 43A: Margin Comparison SW 900 lb. March & April